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INTERRELATIONSHIP OF IN-SITU ROCK PROPERTIES,  
EXCAVATION METHOD, AND MUCK

H. F. Haller, et al

Holmes and Narver, Incorporated

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## Semi-Annual Technical Report No. 1

# INTERRELATIONSHIP OF IN-SITU ROCK PROPERTIES, EXCAVATION METHOD, AND MUCK CHARACTERISTICS



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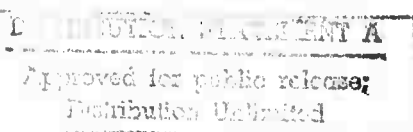
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## 13. ABSTRACT

Reports results of research to correlate the properties of in-situ rocks with materials handling properties of muck and parameters of excavation systems. Goals are to develop methods for predicting muck characteristics from collected data and for selection of transport equipment through the Muck Designation Number concept. Muck sample, rock, and operating data collection, testing methods, data processing, development of MDN's, preliminary regression analyses, and equipment selection are described.

Data available 8/31/72 from 50 samples at 23 sites (16 samples from 8 sites in 1972) is presented in raw data printout and narrative-graphic summary form, showing lithology, rock properties, operating data, and muck properties. Tentative MDN's are described by composite size and distribution curves, with preliminary regression analyses of 27 data sets and prediction accuracies of over 90 percent. Applications to equipment selection/design include input for design formulae used in mathematical models of belt and hydraulic conveying systems.

DOD implications include more rational transport equipment selection and design, with resultant speed and cost benefits. Recommended additional research includes sampling operations and formations not previously available, resampling to improve the confidence level of the data, dynamic testing for coefficients of rock strength in addition to current tests, and predictor refinements.

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## KEY WORDS

## LINK A

## LINK B

## LINK C

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Transport Equipment Selection/Design

Materials Handling in Tunnels

Muck Transportation

16



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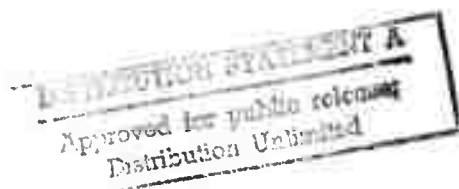
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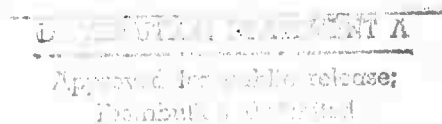
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## FOREWORD

This report presents the results of research performed during 1971 and 1972 into the interrelationships of in-situ rock properties and the characteristics of muck produced by various excavation methods. The authors wish to express their appreciation and that of Holmes & Narver, Inc., for the assistance provided by the many U. S. Bureau of Mines and Holmes & Narver staff members, as well as those individuals and organizations listed below who also participated in the program.

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## INTRODUCTION AND SUMMARY

### PURPOSE

The purpose of the program is to develop a method for predicting the materials handling properties of muck from the engineering properties of rock and the parameters of excavation systems, and a means of selecting the most suitable transportation equipment for the muck through the concept of Muck Designation Numbers (MDN's).

MDN's range in whole numbers from 1 through 7. MDN 1 describes muck with a large maximum piece size, more than 5 percent plus 6-inch material, and a predominant distribution in the plus 1/2-inch size range. The maximum size of MDN 7 is relatively small, the predominant distribution is minus 1/2 inch, and more than 20 percent is minus 200 mesh in size. Intermediate numbers range in size and size distribution between end points. The concept recognizes that muck characteristics vary with excavation methods as well as rock properties.

### SCOPE

This report describes results of research performed in the first half of a contract initiated on February 16, 1972, for a 14-month period. The work is a continuation of a previous 12-month contract of which the results also are covered to summarize the total accomplished and the current status of the program.

### CONCLUSIONS

Program activities have included sample and data collection, physical testing, data storage and processing, development of tentative MDN's, preliminary correlation with rock properties, and establishing the parameters of muck handling systems.

Regression analysis of seventeen sets of rock property, Raise Boring Machine (RBM), and Tunnel Boring Machine (TBM) data produced a predictor equation with an apparent accuracy over 90 percent. Analysis of 10 sets of rock data with conventional excavation parameters produced an accuracy of nearly 100 percent. Inclusion of additional data is expected to improve prediction reliability.



Predictor accuracy probably will not be maintained at preliminary levels, and appropriate parameters remain to be developed for shield and drag cutter TBM's. However, it can be concluded that MDN's are predictable within the limits of reasonable accuracy for the majority of rocks and methods sampled under the program.

Preliminary analysis also shows that MDN data can be used as input for design formulae and performance-cost models of belt and hydraulic conveying systems.

## REFERENCE TO DETAILS

Details of the topics summarized below are arranged under the same headings in the report.

## SUMMARY

### 1. Technical Problems

Inadequate subsurface information on new tunnels limits the effectiveness of construction planning and forces contractors to base bids on methods and equipment which may not suit the job. Loss of time, lives, and money has often resulted.

Estimates of the volume of tunnel construction made several years ago focused attention on the importance of a more logical approach to methods and equipment selection. The advisability of increasing excavation speed while reducing costs has been reemphasized by recent studies which show that prior tunneling forecasts were conservative.

Muck transportation obviously is a major factor in tunnel cost; improvements would reduce tunnel costs significantly. Knowledge of the basic properties of a material is fundamental to improvement of handling techniques. Prior to the inception of the MDN program, however, practically no information had been collected on muck characteristics; and correlations between muck properties, the properties of the in situ rock, and the components of rapid excavation systems had not been established. These data are essential as a basis for optimum selection from the transportation systems in current use and for development of the high speed systems required in the future.

## 2. General Methodology

The research plan is to collect muck samples, lithologic and operating data, and rock specimens, where necessary, from operating tunnels; determine muck characteristics and rock properties by physical testing; correlate and analyze rock and muck properties and quantify relationships through MDN's; and correlate rock and muck characteristics, MDN's, and the components of rapid excavation systems with muck transport system capabilities.

Lithologic data consists of descriptions of rocks, their classification by probable origin and subsequent alteration, and Rock Quality Designations (RQD's) which indicate the frequency of discontinuities. Operating data includes descriptions of the equipment and methods used in the total excavation system. Rock test data includes unconfined uniaxial compressive strength, dry unit weight, hardness, and stress-strain relationships known as Young's modulus and Poisson's ratio. Commercial muck test data includes size distribution, shape, moisture content, dry loose unit weight, and abrasiveness. Additional muck tests by the Pittsburgh Mining and Safety Research Center (PMSRC) determine Atterberg Limits, potential volume change, specific gravity, angles of repose, slide, and internal friction, apparent cohesion, and bulk density.

## 3. Technical Results

### 3.1 Site Selection

A list of current and scheduled tunnels, originally compiled to assure that program objectives could be met, has been revised periodically. The current list is included in Appendix A. Sites for data and sample collection were selected with emphasis on mechanical operations in hard rock. In the first year, some soft rock and conventional tunnels were included as examples of unusual advance rates and systems. In the current program, conventional operations in hard rock at deep mines have been sampled at client request.

### 3.2 Sample and Data Collection

In the current program, operating data and sixteen muck samples were collected from eight sites. Totals for the program are 50 samples from 23 sites. Resampling at four sites confirmed the reliability of initial results. All other samples reflect differing lithologies, operating methods, or equipment.

Rock specimens for engineering property tests have been collected from 39 formations at 21 sites. Nineteen of the specimens, some of which represent formations sampled in 1971, were collected from nine sites in 1972.

Two shield, two RBM, 18 conventional, and 28 TBM operations have been sampled to date. Rock types sampled include four classified as Very High Strength, 20 High Strength, four Medium, 20 Low, and six Very Low Strength. Those remaining to be tested are expected to include three High Strength, six Medium, and two Low Strength classifications. A basis for these classifications follows in the body of the report.

### 3.3 Physical Testing

Standard tests, approved by the American Society for Testing Materials and/or the U. S. Bureau of Mines, were selected for use by commercial laboratories to ensure consistency of results.

Contracts to perform muck tests were negotiated with 18 commercial laboratories. Samples were delivered for testing and shipment of fractions to the U. S. Bureau of Mines, PMSRC, for additional tests. Under the current contract, the volume of the fractions has been increased from 2 to 4 cubic feet. At the end of the reporting period, muck tests by commercial laboratories had been reported on 46 sets of samples and on 41 sets by the PMSRC.

Contracts to perform rock tests have been negotiated with five commercial laboratories. One laboratory is now performing all rock tests. Of the 39 sets of rock specimens which have been collected, 31 test suites have been completed. Stress-strain data from testing initiated in 1972 was obtained on 11 rocks, including four sampled in 1971. Results from Schmidt hardness tests on rock cores, also initiated in 1972, have not been consistent. Modification of test methods is contemplated. Initial abrasiveness tests are planned for the third quarter of the contract.

### 3.4 Data Processing

Formats were developed for storage and printout of lithologic rock, muck, and tunnel data: data received to date has been stored on punch cards and printouts of these data are included as Appendix B. A form was developed for narrative and graphic presentation of data. These "System Data Sheets" are included as Appendix C.

### 3.5 Development of MDN's

Size distribution curves from initial sampling varied distinctly, generally as had been expected; and an algorithm to correlate MDN's, in situ rock properties, and excavation methods was developed, as described in Appendix D.

Continued sample testing produced some curves which fit well with the initial curves, and others which required establishing additional categories. Using the data available at the end of the first year, curves of similar form were plotted together, and preliminary MDN's were assigned. The resulting composite curves are shown in figures 3-3 through 3-11.

Initial regression analyses produced the predictor equations described in the "Conclusions" section, indicating accuracies over 90 percent for RBM/TBM and for conventional operations. Computer input data are shown in Section 3, and the output tabulations are shown as Figures 3-1 and 3-2.

Additional iterations will be performed when the data collected in 1972 is in final form. Values for Young's modulus, Poisson's ratio, and Schmidt hardness resulting from current tests will be substituted for the less important parameters and inferred values used in current analyses. Current efforts to obtain data on net torque for TBM's and RBM's, and to develop operating parameters for drag cutter TBM and shield operations will be continued.

### 3.6 Transport System Selection

A list of equipment capabilities, system constraints, and MDN applications, prepared for the Annual Technical Report for the first year, has been included as Appendix E.

Belt and hydraulic conveying system design parameters and available parametric mathematical models of these systems were studied under the current program. Collected muck property data is appropriate as input to design formulae and the models. Some clarification of design parameters and refinement of the models is planned for the second half of the current program. An example of MDN data use in design of an hydraulic system is in progress; a comparison between an existing installation and a belt conveyor design based on MDN data, and examples of MDN applications to other systems are planned.

#### 4. DOD Implications

Data accumulated under the program are nonexistent elsewhere in rapid excavation technology and can provide a more rational basis for selection of materials handling systems for excavation methods in current use. These data will also be invaluable to the design of the equipment required to match the improved advance rates resulting from current excavation research. As alternatives to design of systems to handle a specific type of muck, MDN data can be used to select process equipment to change muck characteristics to suit a system, or to select separation and supplementary haulage equipment for the oversize fraction of muck which cannot be handled by a continuous system which is otherwise well adapted to a site.

The MDN program provides basic data required for a rational engineering approach to problem solutions in a most important subsystem of the rapid excavation process. It will show examples of data application and should be used to indicate the areas in which research and development of modifications or new methods would be most productive.

#### 5. Implications for Further Research

##### 5.1 Sample and Data Collection

Recommendations for further research are based in part on the following projection of formations and excavation systems for which data is expected to be available at the end of the current contract.

Excavation Method	Rock Strength					Total
	Very High	High	Medium	Low	Very Low	
<u>Conventional</u>	3	9	5	1	1	19
<u>Shield</u>	0	0	0	0	2	2
<u>Machine</u>						
Drag Cutters	0	1	1	2	1	5
Disc Cutters	2	7	5	1	0	15
Roller Cutters	0	4	1	0	0	5
Combination Cutters	0	3	1	1	2	7

To be consistent with good sampling and testing practice, data reliability should be confirmed by repetition of all single samples. Eleven sites previously sampled once are expected to be available in 1973. Statistically, the number of samples used in development of a predictor equation should be greater than the number of variables in the analysis. To improve prediction reliability additional samples, detailed in the body of the report, should be collected from all types of TBM's in selected formations.

To demonstrate variations in muck characteristics with rock properties, conventional and selected TBM samples should be collected from the Medium and Low Strength rocks.

To provide data on the full range of rock types, stratified volcanic and fine grained igneous rocks should be sampled. Sampling muck from tests of unusual rock breaking techniques which may become the standards of the future should be initiated to provide data on the muck for which transport systems will be required.

## 5.2 Physical Testing

Continued development of testing methods to provide consistent results from Schmidt hardness tests is recommended because of the speed, low cost, and nondestructive nature of the only test for a dynamic rock property in current use.

Investigation of the Protodyakonov test for resistance to fragmentation is recommended to determine the effect of a second dynamic property on prediction accuracy.

## 5.3 General

Potential improvements in systems components which require the application of techniques which are technically sound but not yet developed to a point of practical application may appear in the collection and analysis of program data. These should be identified as attractive areas for research and development.

## 6. Special Comments

A Schmidt impact rock test hammer and two self rescuers were purchased during the reporting period for use in the program. No invention has been made in the course of the work performed under this contract.

## 1. TECHNICAL PROBLEMS

The effectiveness of planning for new tunnels has been limited by the quantity and quality of information concerning subsurface conditions which has been available. Owners and owner-agencies often have been reluctant to collect data on the properties of materials to be excavated, or to publish information which has been collected. Interested contractors are forced to base proposals on inadequate information about conditions to be encountered, and to base cost estimates on methods and equipment which may not be well suited for conditions as they exist. Generally, significant allowances are made both for contingencies which can be anticipated and for those which cannot be foreseen.

The importance of a more logical approach to selection of methods and equipment for tunneling became apparent when the volume of this work probable in the future was estimated several years ago; it has been reemphasized by more recent studies which indicate that prior estimates were conservative. Wider application of tunnel boring machines, which require rock property data for design, and of an engineering approach to ground support have influenced owner and agency policies to the extent that collection and dissemination of more and better quality exploratory information appears to be a current trend.

Progress has been made and is continuing in research to determine relationships between rock properties, drillability, excavation, and support requirements. Prior to inception of the program described in this report, practically no information had been collected on the characteristics of the muck produced by various excavation methods, and correlations between the engineering properties of rock, muck characteristics, and the components of excavation systems had not been established.

In the absence of muck characteristic data, an adequate basis for selection of optimum transportation methods and equipment does not exist, and tunneling progress and cost have been affected adversely. Muck data are also basic requirements for engineering the improvements to existing transport systems and the development of the new systems which will be necessary to keep pace with the higher rates of excavation predicted for the future.

## 2. GENERAL METHODOLOGY

Objectives of the program are to develop a method for predicting materials handling properties of muck from the in-situ properties of rock and a means of selecting the most suitable transportation equipment for muck produced by various excavation systems. The major emphasis is on mechanical excavation of hard rock. However, some soft rock and conventional operations are included as examples of unusual advance rates, equipment, and operating methods.

The program plan is to collect muck samples and operating data from tunnels and mining projects in rock of known properties; collect specimens from sites where the in-situ properties are unknown; determine muck characteristics and rock properties by physical testing; correlate and analyze rock and muck properties and quantify relationships through the concept of Muck Designation Numbers (MDN's); and to establish correlations between rock and muck characteristics, MDN's, the components of rapid excavation systems, and selection of muck transport equipment.



### 3. TECHNICAL RESULTS

#### 3.1 SITE SELECTION

A list of operating and scheduled tunnels, prepared originally to assure that program objectives could be met, has been revised periodically. The latest revision is included as Appendix A. Six of the tunnels listed are expected to be completed in 1972. Letter inquiries inviting program participation by off-continent tunnel operators met with no response. These tunnels have been deleted from the list.

Tunnel contractors, although under no obligation to participate in the program, have been most cooperative. Operating mine cooperation has been equally good, although access usually requires more operator support, and the impact of economic conditions has reduced emphasis on research. Scheduling sampling and data collection on a strictly noninterference basis and full observance of safety requirements have been important in gaining operator acceptance.

Early planning assumed that one basis for site selection would be the availability of rock property data at specific sites. Experience proved that collection of these data is necessary from the majority of locations, and the program was modified to reflect this requirement.

In the first half of 1971, it became apparent that sampling tunnel operations in a wide range of rock strengths and excavation techniques would be necessary to demonstrate that muck characteristics vary distinctively with rock characteristics and operating methods. The program plan was modified to provide for data collection in the variety possible within the limits of time and availability, and additional funds were provided by contract modification to enlarge the scope of field sampling.

In the first year of the program, sites were selected to provide one-third of the samples from conventional excavation. In the current year seven conventional and nine mechanical operations have been sampled, and one more of each is expected in the second half of the year.

In response to a client request to obtain samples and data from conventional operations in strong rocks at maximum depth during 1972, sites were selected for field work in two quartzites at 7,094 feet and

6,110 feet, a phyllite at 6,200 feet, a quartz monzonite at 2,075 feet, a conglomerate at 3,960 feet, and a graywacke at 3,480 feet below the surface. At some sites, planned sampling of stronger rocks and/or at greater depths could not be accomplished because of site conditions.

### 3.2 SAMPLE AND DATA COLLECTION

Muck samples and operating data have been collected from 23 mine and tunnel sites. Of 50 samples, 11 were collected from sites visited only once. Resampling was done in similar formations at four sites to confirm the reliability of initial results. All other samples reflect differing lithologies, operating methods, or equipment.

The scope of collecting in-situ rock data has been greater than was anticipated originally, because formations encountered in most locations could not be correlated with the existing rock data. Rock specimens or cores have been collected for engineering property tests from 39 formations at 21 sites.

Two shield operations, two RBM, 18 conventional, and 28 TBM operations have been sampled to date. Rock types classified include four Very High, twenty High Strength, four Medium, five Low, and six Very Low Strength. Rocks which remain to be tested are expected to include three High Strength, six Medium, and two Low Strength classifications.

Nine of the sampled sites are no longer available for field work. Of the remaining sites, one is expected to complete excavation in October of 1972.

Early in the 1972 program a request was received from the Project Officer to increase the volume of samples provided for testing at the Pittsburgh Mining and Safety Research Center (PMSRC) from 2 to 4 cubic feet. Sampling and laboratory procedures were modified to comply with this request.

Muck samples collected are representative of the material as it reaches the transportation system. Muck produced mechanically normally is sampled as it leaves the conveyor which is integral with the machine. Conventional muck is sampled by channeling. Pieces which are too large for practical delivery to a laboratory are measured, and calculated weights in the various size ranges are added to adjust the screen test results. Rock specimens, or rock cores when available, are collected in sizes large enough to permit the preparation of six test specimens approximately 2-1/8 inches in diameter by 4-1/4 inches long.

Operating data in the first year of the program was collected in sufficient detail to permit inclusion of all of the components of the tunneling system in the analysis and selection of optimum transportation subsystems for specific MDN's and tunnel configurations. Experience in data analysis has indicated a need for more precise thrust, torque, and cutter data than was expected to be required for mechanical tunneling. In the current year, these data are being collected for most of the TBM operations sampled to date.

### 3.3 PHYSICAL TESTING

Published test methods were reviewed in detail to ensure that tests performed by commercial laboratories would yield consistent results. The following American Society for Testing and Materials (ASTM) standard methods were selected as specifications in the first year of the program.

- C566-67: Total Moisture Content by Drying
- C156-67: Sieve or Screen Analysis of Fine and Coarse Aggregates
- C117-69: Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing
- C29-69: Unit Weight of Aggregate, Loose Weight Determination
- C170-50: Compressive Strength of Natural Building Stone

Specifications for the last test procedure were modified to provide for greater accuracy in specimen preparation so that results will be comparable to those reported by other rock property research programs.

Review of the data collected in the first year led to a decision to test rock specimens for deformation moduli in the current program to provide additional data for regression analyses. Following a review of test methods, ASTM Standard C170-50 was replaced by the following procedure, and additional standards were developed to conform with the practices followed by U. S. Bureau of Mines research centers in measuring strains.

- D2938-71: Unconfined Compressive Strength of Rock Core Specimens

Results of hardness tests by the Shore scleroscope, a laboratory instrument which tests hardness by rebound, are available for only three of the rock formations sampled. Additional tests by this method were found to be beyond the scope of this study. Hardness testing by the Schmidt hammer, a portable device which also tests rebound hardness, is nondestructive and relatively inexpensive and was specified for inclusion in the 1972 program. A hammer was purchased for use in testing tunnel walls and rock specimens.

Standard methods of testing abrasiveness were reviewed to determine the feasibility of collecting these data from tests on muck samples. The standard ASTM tests were found to measure the resistance of the sample to abrasion, rather than the abrasive effect on other materials. The latter is the property of greater interest in materials handling, and a machine designed for such testing was located by the Project Officer at the PMSRC and will be available to the program in the second half of the current contract period.

Modification of the standard test procedure was found necessary in testing muck from some low strength rocks. Screen testing the samples in the natural state was performed prior to the standard tests to avoid distortion of the curves caused by the disintegration of material during the wash screening which normally precedes dry sieve analysis. Natural screen test results are identified and shown as dotted lines on the size distribution curves.

Contracts to perform muck tests have been negotiated with 18 commercial testing laboratories. Collected samples were delivered for testing and shipment of minus 2-inch fractions to the U. S. Bureau of Mines, PMSRC, for additional tests to be performed at this facility. At the end of the reporting period, tests by commercial laboratories had been reported on 46 sets and by the PMSRC on 41 sets of muck samples. One set of samples tested commercially was lost in transit to the PMSRC.

Contracts to perform tests on rock specimens have been negotiated with five commercial laboratories. One laboratory is now performing all rock tests, which assures uniformity of results, but also delays some tests when the volume of work is high. Two sets of specimens destroyed in preparation for testing in 1971 were replaced in 1972. A total of 39 sets of rock specimens have been collected, on which 31 reports have been received, and 8 sets remain to be tested. Stress-strain data was obtained on 11 rocks, including 4 collected in the 1971 program. Specimens yet to be tested appear to be of the necessary quality for stress-strain testing.

Initial Schmidt hardness tests by project personnel on walls of tunnels gave results which correlated well with those reported by other researchers on similar rocks. Initial tests on 11 core specimens showed no obvious correlation with field tests or with values obtained from the hardness-compressive strength relationships established by previous investigations. Further trials on hand lapped core specimens and a modified cradle indicated that lapping raised test values somewhat nearer those observed in tunnel wall tests. Some variation in values appears to be associated with core straightness. The cost and results of testing polished flat surfaces is being investigated.

### 3.4 DATA PROCESSING

A format was developed for computer printout of lithologic, rock, muck, and tunnel data. Test results received to date have been stored on punch cards. Printouts of these raw data are included as Appendix B. Blank spaces on the printout indicate that data is not available on the date of the report.

Narrative and graphic summaries were prepared to combine these data with descriptions of the excavation systems from which rock and muck samples were taken, and are included as Appendix C. Rock strength classifications are based on uniaxial compressive strength, and conform with those proposed by D. U. Deere, et al., in the "Engineering Classification and Index Properties for Intact Rock," University of Illinois, 1966. These classifications are:

Very High Strength	-	Greater than 32,000 psi
High Strength	-	16,000 - 32,000 psi
Medium Strength	-	8,000 - 16,000 psi
Low Strength	-	4,000 - 8,000 psi
Very Low Strength	-	Less than 4,000 psi

Grain size classifications of igneous rocks, from A. Johannsen's "A Descriptive Petrology of Igneous Rocks," 1931, are used as follows:

Very Coarse	-	Above 3 cm
Coarse	-	1 to 3 cm
Medium	-	1 to 10 mm
Fine	-	Below 1 mm

From J. F. Kemp's "A Handbook of Rocks," 1950, sedimentary rocks of fragmental grains above 2 mm, are classified as conglomerates, while those below 2 mm in size are classified as sandstones or siltstones.

Symbols used to describe the shape of particles in the sample fractions between screen sizes are the following:

A - Angular	S - Subangular
P - Platy	R - Rounded
E - Elongated	C - Cubic
I - Irregular	Sp - Spheroid

The curves show the percentage of the total sample weight passing one screen size and retained on the next. Screen sizes below 1/2 inch were selected to provide openings which become progressively smaller by approximately 50 percent as shown below:

Screen Size	#4	#8	#16	#30	#50	#100	#200
Nominal Square Openings, Inches	0.187	0.094	0.047	0.023	0.012	0.006	0.003

The abbreviation NA is used to indicate that an item of data is not available.

### 3.5 DEVELOPMENT OF MDN'S

In accordance with the program plan, which provided for placing major emphasis on data collection during the first year, analysis of data and development of MDN's has been preliminary. As data first became available, test results were reviewed to confirm the validity of the conceptual classification criteria. Based on a plan of classification by materials handling characteristics, the proposed designation system employed seven numbered categories in which to group excavation products by size and size distribution. Numbers were assigned in a progression from No. 1 for muck with a relatively large maximum piece size and a predominant distribution in the 1 inch to 200 mesh range to No. 7, in which the maximum size is relatively small and the predominant distribution is in the minus 50 mesh sizes. The concept also recognized that muck characteristics would vary with the excavation method and contemplated modifying the MDN's to distinguish between excavation techniques.

Initial field work was scheduled at sites where rock strengths varied over a wide range and which would provide examples of shield, machine, and conventional operations. The size distribution curves of the muck from these sites (Identification Numbers H-1, 5-1, CL-1, NAST-1, and SF-1, Appendix C), varied distinctly, in general accordance with the

criteria, except that the size range of the predominant distribution was somewhat higher than had been inferred.

Using the initial data as a guide, a preliminary algorithm was developed for data analysis to correlate MDN's, in-situ rock properties, and excavation methods. The quantitative relationship sought was a predictor equation, obtained by multiple regression of the physical property data obtained from the rock sample tests and a predictor equation for the MDN. A discussion of this technique is included as Appendix D.

During algorithm development, resampling at four of the original sites confirmed the distinctive shape of the size distribution curves. Sampling at other sites produced some curves which fit well into the original categories and others which were distinctive enough to suggest establishing additional categories. Using the data available at the end of the first year, curves of similar form were plotted together, and tentative designation numbers were assigned. The resultant composites are shown as Figures 3-3 through 3-11.

The "T" prefix was added to all MDN's to indicate the preliminary nature of the assignments. Parameters available for the analysis of all samples included values of uniaxial compressive strength ( $f_c$ ), rock quality designation (RQD), and dry unit weight (DUW) for which quantitative values were determined by field observation and testing. To avoid reducing data derivatives to extremely small values, rocks with compressive strengths of 1K psi or less have been assigned arbitrary strengths of 1. Rock classifications by origin were quantified as igneous = 1, metamorphic = 2, and sedimentary = 3; and ground water occurrence was quantified as dry = 1, minor = 2, and wet = 3. The order and magnitude of the number assignment is immaterial since these are modified in the analysis in nearly any case. Schmidt hardness values (H) are converted Shore values, where available, or inferred from data published by D. U. Deere, et al., in the "Engineering Classification and Index Properties for Intact Rock" referenced above.

Cutter spacing (CS) appeared to be an important TBM characteristic. Average dimensions were available for disc cutter and some drag cutter machines. For roller cutters for which no kerf pattern is apparent, values were obtained by dividing the body spacing by the number of buttons adjacent to a line along the face of the cutter and parallel to the axis of rotation. No kerf spacing was available for Alpine and Atlas-Copco TBM's. Net thrust values per square foot of face area (T) were available for TBM's with the same exceptions.

No appropriate operating parameters were available for the Alpine and Atlas-Copco machines or for the shield operations sampled, and the number of observations was insufficient to warrant analysis as a special case.

Parameters peculiar to conventional operations, face area per drill hole (A/H), and explosives per cubic yard excavated (PF) were calculated from collected data.

An initial analysis using rock properties alone led to a predictor equation for which the accuracy, described by the multiple correlation coefficient, was 72 percent. This was expected since operating parameters were not included. Seventeen sets of data were analyzed for machine operations using the values tabulated below:

DATA FOR ANALYSIS, MACHINE OPERATIONS										
Column		1	2	3	4	5	6	7	8	9
Ident. No.	Obs. No.	MDN	Class	$f_c$	RQD	DUW	H	GW	CS	T
5-1	1	2	3	22	92	166	49	1	0.20	3.56
7-2	2	2	3	22	92	166	49	1	0.20	2.91
LAW-2	3	3	3	19	100	160	42	1	0.20	4.28
LAW-3	4	3	3	19	100	160	42	1	0.20	4.28
LAW-4	5	3	3	19	100	160	42	1	0.20	3.76
MIL-1	6	4	3	36	85	166	50	2	0.16	6.09
MIL-2	7	4	3	36	85	166	50	2	0.18	6.09
QL-1	8	4	2	11	30	165	37	2	0.18	3.53
CL-1	9	5	2	9	10	174	45	2	0.09	5.09
NAST-2	10	5	1	18	90	167	55	2	0.09	3.89
NAST-4	11	5	1	24	90	160	55	2	0.09	8.45
LK-5	12	5	1	32	92	165	55	1	0.24	4.46
LK-6	13	5	1	7	86	137	50	1	0.13	17.20
NAST-1	14	5	1	18	90	167	55	2	0.09	3.89
LAY-1	15	6	3	10	84	150	47	1	0.24	2.73
NAV-1	16	6	3	2	70	142	25	1	0.30	1.31
NAV-2	17	7	3	1	60	117	25	1	0.30	0.37

Results of stepwise regression, as shown in detail on Figure 3-1, following, indicate an accuracy of slightly more than 90 percent with a standard error of 0.8360 and the listed residuals.



MULTIPLE CORRELATION COEFFICIENT..... 0.9081  
 F FOR ANALYSIS OF VAR. (D.F. = 8, 8) 4.7026  
 STANDARD ERROR OF ESTIMATE..... 0.8360

VARIABLE	REG. COEFF.	STD. ERR-COEFF.	COMPUTED T
5	-6.89554E-02	3.55858E-02	-1.93772
7	2.29717	1.14621	2.00414
2	-.469846	.381356	-1.23204
8	17.7298	11.4412	1.54964
3	-6.63157E-02	5.89690E-02	-1.12459
6	.104435	6.65627E-02	1.56898
4	-6.17628E-03	1.61827E-02	-.381659
9	-3.90019E-02	.103588	-.376511

INTERCEPT(A) 6.98974

# TABLE OF RESIDUALS

OBS.	Y OBSERVED	Y ESTIMATED	RESIDUAL	STD. RESID.
1	2.000	2.928	-0.928	-1.110
2	2.000	2.953	-0.953	-1.140
3	3.000	2.732	0.268	0.320
4	3.000	2.732	0.268	0.320
5	3.000	2.752	0.248	0.296
6	4.000	3.637	0.363	0.435
7	4.000	3.991	0.009	0.011
8	4.000	5.270	-1.270	-1.519
9	5.000	4.084	0.916	1.095
10	5.000	5.037	-0.037	-0.044
11	5.000	4.944	0.056	0.067
12	5.000	4.574	0.426	0.509
13	5.000	5.231	-0.231	-0.276
14	5.000	5.037	-0.037	-0.044
15	6.000	5.409	0.591	0.707
16	6.000	5.399	0.601	0.718
17	7.000	7.288	-0.288	-0.345

COMPUTER OUTPUT-TBM AND RBM DATA ANALYSIS.

FIGURE 3-1

Ten sets of data were analyzed for conventional operations, using the values tabulated below:

DATA FOR ANALYSIS, CONVENTIONAL OPERATIONS										
Column		1	2	3	4	5	6	7	8	9
Ident. No.	Obs. No.	MDN	Class	$f_c$	RQD	DUW	H	GW	A/H	PF
LK-1	1	1	1	25	83	162	55	1	5.4	4.0
LK-2	2	1	1	28	83	165	55	1	5.4	4.0
LK-3	3	1	2	26	80	178	50	1	5.0	5.0
LK-4	4	2	2	14	70	181	47	1	4.4	5.5
GA-1	5	3	1	35	96	161	55	1	2.1	6.1
11-3	6	3	3	22	90	152	43	1	5.1	3.5
H-1	7	3	1	32	80	162	52	2	2.6	5.5
NAST-3	8	3	1	13	90	152	42	2	2.2	6.3
H-2	9	3	1	39	80	164	55	2	2.6	5.6
WNG-2	10	7	3	1	30	125	20	3	2.5	5.0

Results of the analysis, as shown in detail on Figure 3-2 following, indicate an accuracy of over 99 percent with a standard error of 0.2062 and the listed residuals.

Incorporation of additional data from subsequent field work and testing will improve the reliability of prediction, although it is doubtful that the accuracy indicated for conventional operations will be maintained at the level of the preliminary analysis. In additional iterations of the analysis, it is proposed to substitute values of Young's modulus and Poisson's ratio being accumulated in the current program for the less important parameters. Current efforts to obtain data on effective or net torque for TBM's, to develop appropriate parameters for analysis of the drag cutter TBM and shield MDN's, and to confirm inferred Schmidt hardness values will be continued to provide additional variables for analysis. Analyses with complete data are scheduled for the remainder of the current program.

### 3.6 TRANSPORT SYSTEM SELECTION

A list of equipment capabilities, system constraints, and MDN applications which comprised this section of the annual report of the first year's program is included as Appendix E.

MULTIPLE CORRELATION COEFFICIENT..... 0.9992  
 F FOR ANALYSIS OF VAR. (D.F. = 8, 1) 82.4711  
 STANDARD ERROR OF ESTIMATE..... 0.2062

VARIABLE	REG. COEFF.	STD. ERR-COEFF.	COMPUTED T
5	-1.82976E-02	4.70338E-02	-.389031
9	-.237584	.534353	-.444621
2	.75977	.787339	.964985
7	-1.37212	.48862	-2.80816
4	-3.41264E-02	9.69424E-03	-3.52028
8	-.879842	.801093	-1.0983
3	-3.07083E-02	4.55421E-02	-.674285
6	4.07791E-02	.147084	.277251

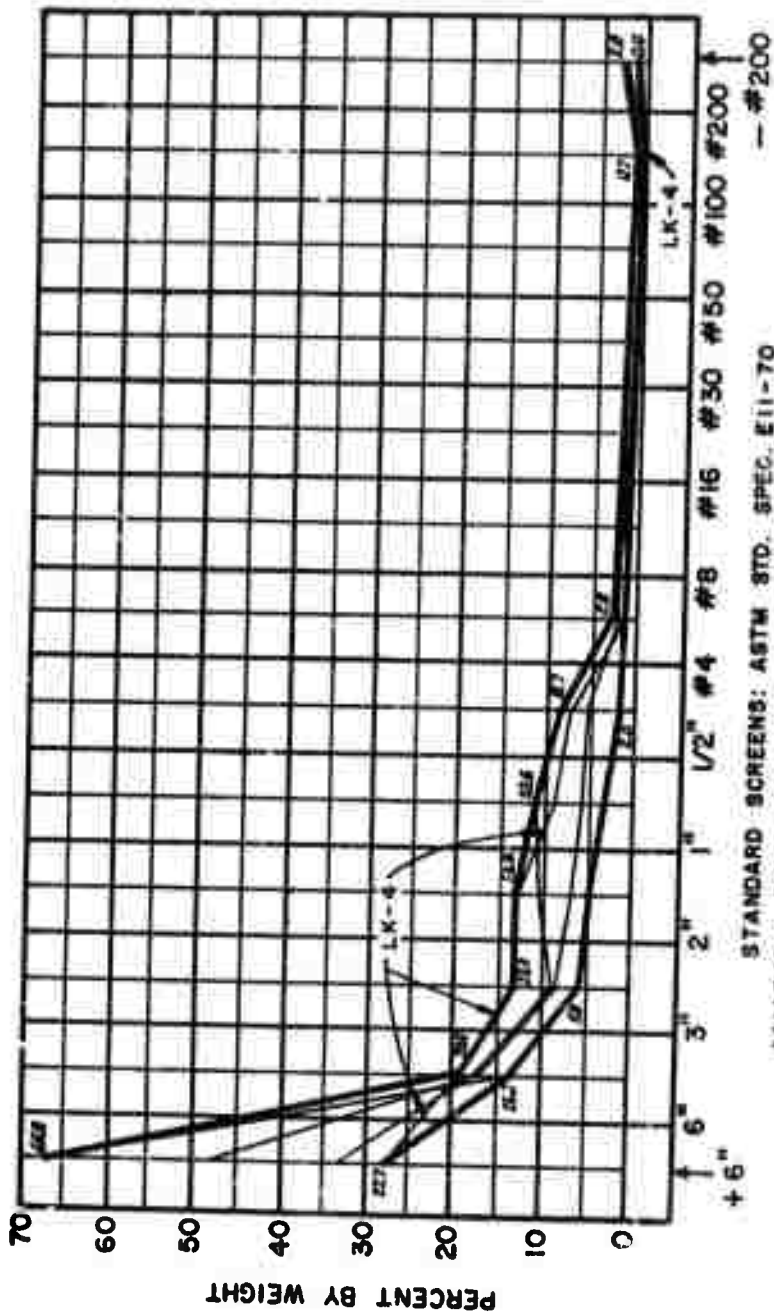
INTERCEPT(A) 15.7937

#### TABLE OF RESIDUALS

OBS. NO.	Y OBSERVED	Y ESTIMATED	RESIDUAL	STD. RESID.
1	1.000	1.065	-0.065	-0.318
2	1.000	0.918	0.082	0.395
3	1.000	1.069	-0.069	-0.336
4	2.000	1.954	0.046	0.221
5	3.000	3.013	-0.013	-0.065
6	3.000	2.983	0.017	0.080
7	3.000	3.115	-0.115	-0.558
8	3.000	2.978	0.022	0.109
9	3.000	2.898	0.102	0.495
10	7.000	7.005	-0.005	-0.022

COMPUTER OUTPUT-CONVENTIONAL DATA ANALYSIS.

FIGURE 3-2



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. BETWEEN SCREENS

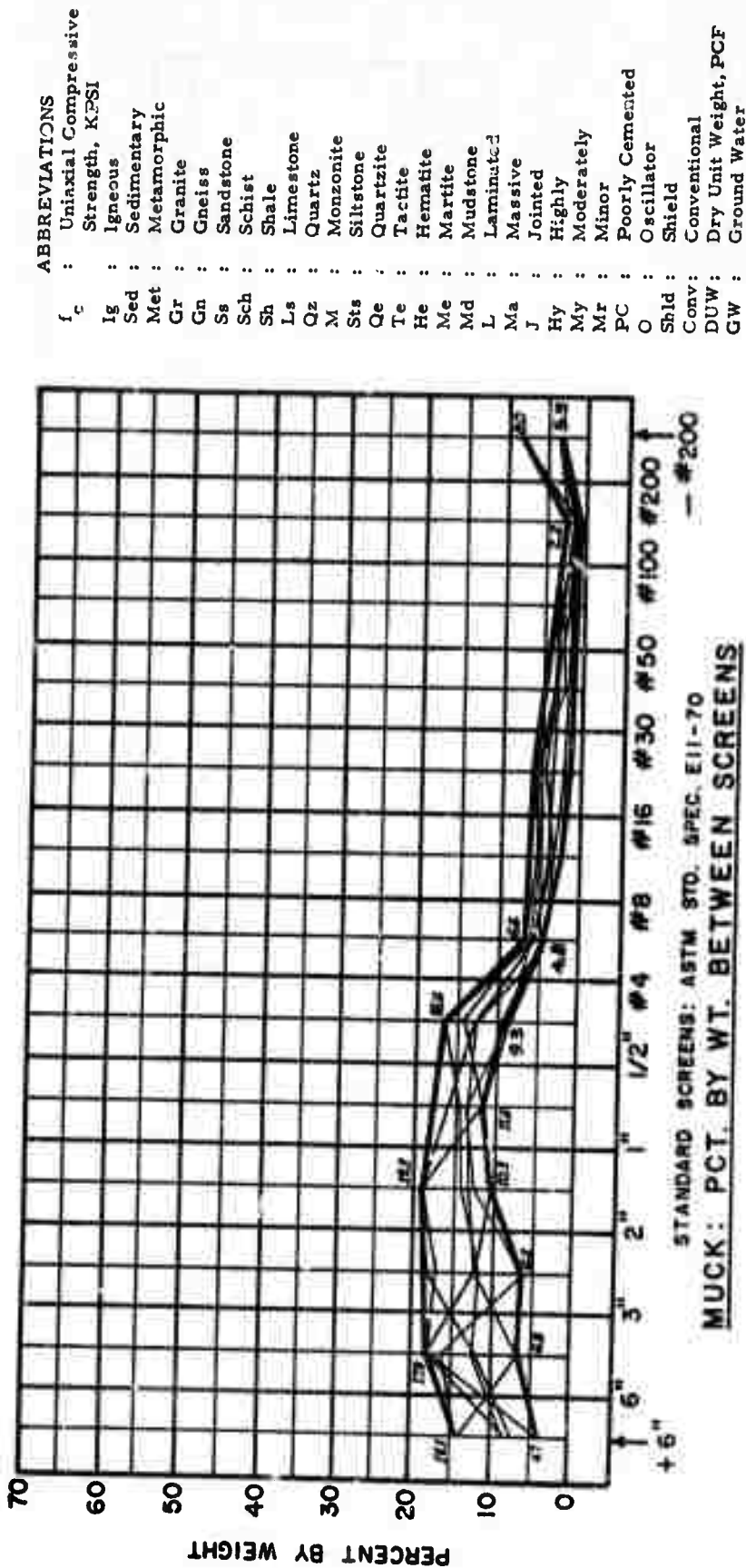
ABBREVIATIONS  
 $f_c$  : Uniaxial Compressive Strength, KPSI  
 Ig : Igneous  
 Sed : Sedimentary  
 Met : Metamorphic  
 Gr : Granite  
 Gn : Gneiss  
 Ss : Sandstone  
 Sch : Schist  
 Sh : Shale  
 Ls : Limestone  
 Qz : Quartz  
 M : Monzonite  
 Sts : Siltstone  
 Qe : Quartzite  
 Te : Tactite  
 He : Hamatite  
 Me : Martite  
 Md : Mudstone  
 L : Laminated  
 Ma : Massive  
 J : Jointed  
 Hy : Highly  
 My : Moderately  
 Mr : Minor  
 PC : Poorly Cemented  
 O : Oscillator  
 Shld : Shield  
 Conv : Conventional  
 DUW : Dry Unit Weight, PCF  
 GW : Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	ROCK PROPERTIES							TUNNEL		SQ. FT. / HOLE	EXPL. #/CY.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	$f_c$	RQD	DUW	HARDNESS*	SIZE, FT.	GW			
LK-1	Conv	T-1	Ig=1	Qz M	Mr J	25	83	162	55	18W x 16	Dry=1	5.4	4.0	4'x 3 x 2'
LK-2	Conv	T-1	Ig=1	Qz M	Mr J	26	83	165	55	18W x 16	Dry=1	5.4	4.0	3-1/2'x 2'x 2'
LK-3	Conv	T-1	Met=2	Qe Te	L My J	26	80	178	50	16W x 14.5	Dry=1	5.0	5.0	2-1/2'x 1'x 1/2'
LK-4	Conv	T-2	Met=2	Te	My J	14	70	181	47	15W x 14	Dry=1	4.4	5.5	27"x 18"x 12"
COL. NO. **		1 2				3	4	5	6		7	8	9	

\*Inferred from D. U. Deere, et al, AD 646 610-1966.

\*\*Regression Data List.

FIGURE 3-3: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-1 AND T-2, CONVENTIONAL



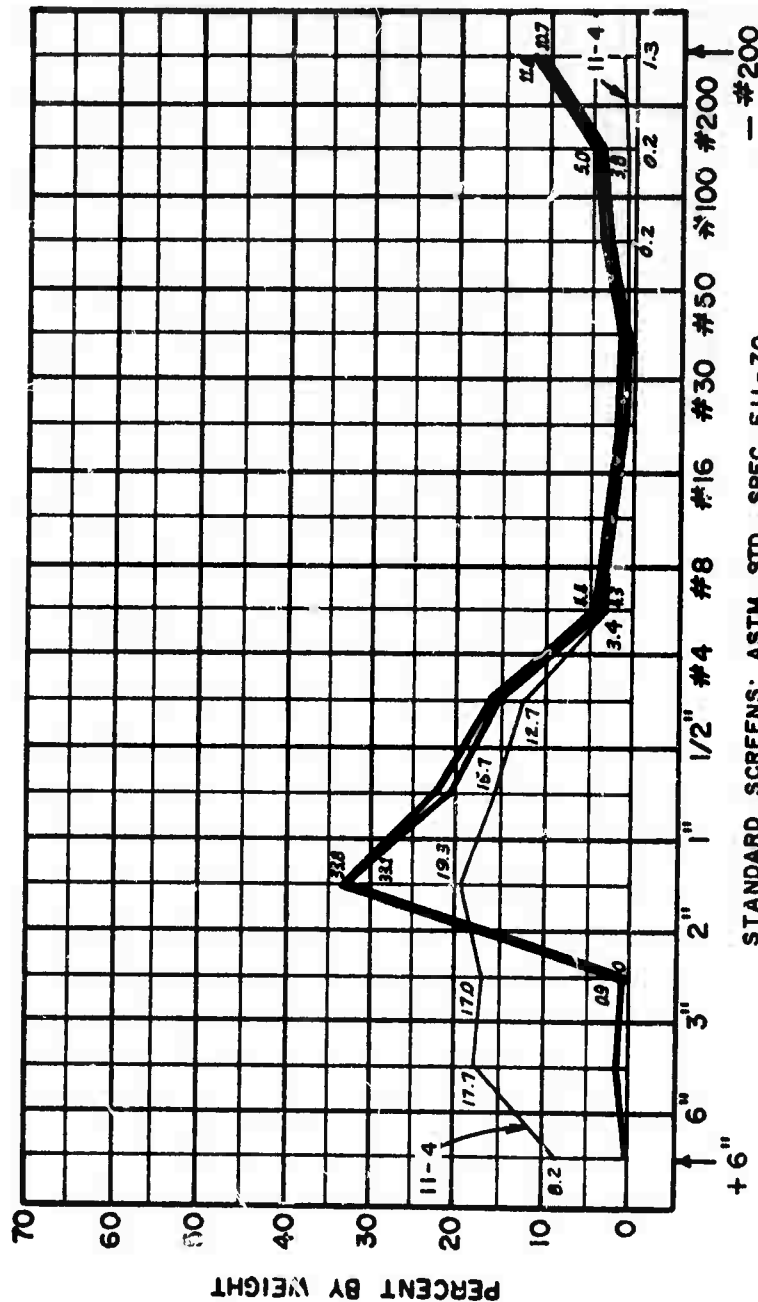
IDENT. NO.	EXCAV. METHOD	MDN	CLASS	TYPE	ROCK PROPERTIES				TUNNEL		SQ. FT. / HOLE	EXPL. #/CY.	MAX. SIZE OBSERVED
					STRUCT.	$f_c$	RQD	DUW	HARDNESS*	SIZE, FT.	GW		
GA-1	Conv	T-3	Ig=1	Gr	Mr J	35	96	161	55	10 x 10	Dry=1	6.1	2-1/2' x 2' x 1'
11-3	Conv	T-3	Sed=3	Sts Sh	Ma Mr L	22	90	152	43	24W x 7.5	Dry=1	3.5	18' x 18' x 4"
H-1	Conv	T-3	Ig=1	Gr	Mr J	32	80	162	52	10 x 10	Mr=2	5.5	3' x 2' x 1'
NAST-3	Conv	T-3	Ig=1	Gr	Mr J	13	90	152	42	16W x 10	Mr=2	6.3	2-1/2' x 1-1/2' x 1'
H-2	Conv	T-3	Ig=1	Gr Gn	Mr J	39	80	164	55	10 x 10	Mr=2	5.6	2' x 1-1/2' x 1'
COL. NO. **		1	2			3	4	5	6		7	8	9

\*Inferred from D. U. Deere, et al, AD 646 610-1966.

\*\*Regression Data List.

FIGURE 3-4: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-3, CONVENTIONAL





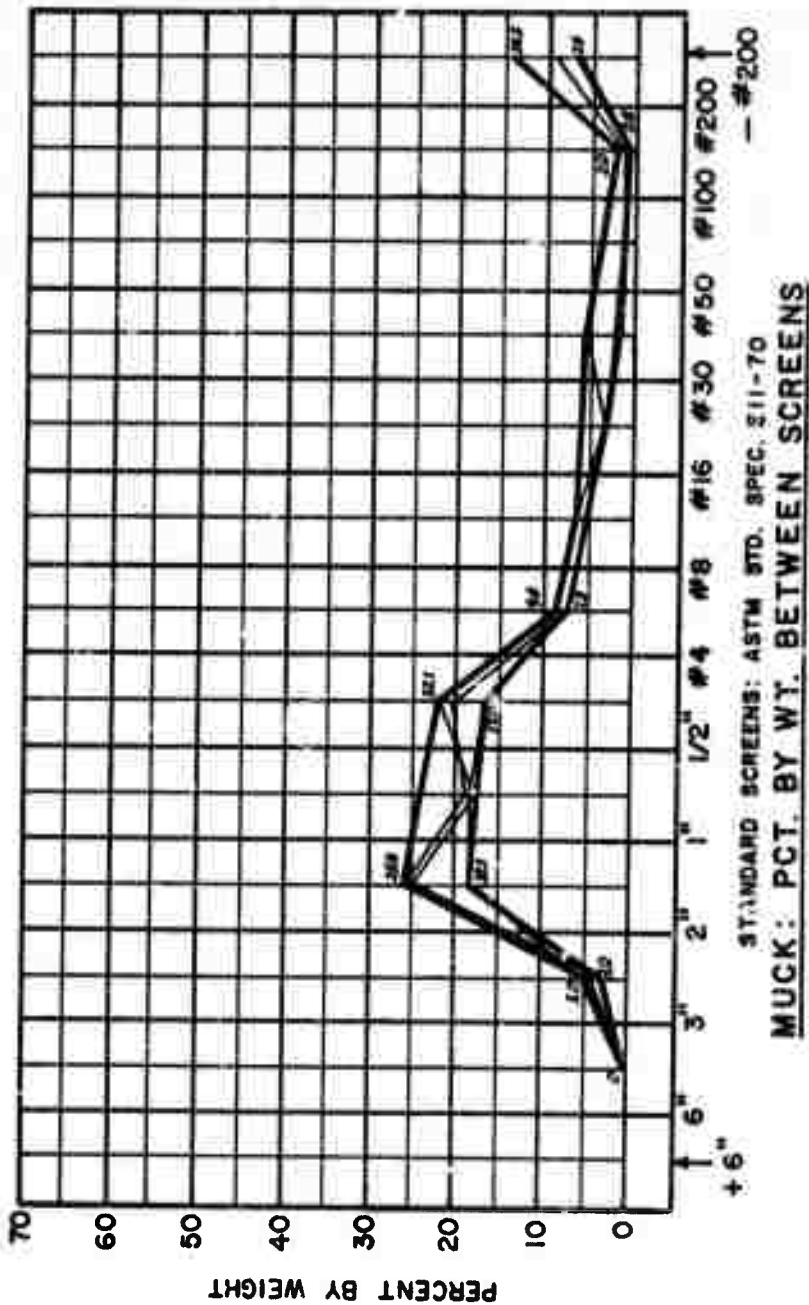
ABBREVIATIONS

$f_c$	: Uniaxial Compressive Strength, KPSI
Ig	: Igneous
Sed	: Sedimentary
Met	: Metamorphic
Gr	: Granite
Gn	: Gneiss
Ss	: Sandstone
Sch	: Schist
Sh	: Shale
Ls	: Limestone
Qz	: Quartz
M	: Monzonite
Sts	: Siltstone
Qe	: Quartzite
Te	: Tactite
He	: Hematite
Me	: Martite
Md	: Mudstone
L	: Laminated
Ma	: Massive
J	: Jointed
Hy	: Highly
My	: Moderately
Mr	: Minor
PC	: Poorly Cemented
O	: Oscillator
Shld	: Shield
Conv	: Conventional
DWU	: Dry Unit Weight, PCF
GW	: Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	ROCK PROPERTIES					TUNNEL		KERF SPACE	THRUST /SQ.FT.	MAX. SIZE OBSERVED	
			CLASS	TYPE	STRUCT.	f <sub>c</sub>	RQD	DWU	HARDNESS*				SIZE, FT.
11-4	TBM	T-1	Sed=3	Ss Sh	Ma Mr L	22	90	166	43	18W x 8.5	Dry=1	8"x 8"x 4"	
5-1	TBM	T-2	Sed=3	Ss	Ma	22	92	166	49	18.08 dia.	Dry=1	2-1/2"x 8"x 3/4"	
7-2	TBM	T-2	Sed=3	Ss	Ma	22	92	166	49	18.08 dia.	Dry=1	3"x 9"x 1"	
COL. NO. 33		1	2			3	4	5	6		7	8	9

Inferred from D. U. Deere, et al., AD 640 610-1966. \*\*Regression Data List.

FIGURE 3-6: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-1 AND T-2, MACHINE



ABREVIATIONS

$f_c$  : Uniaxial Compressive Strength, KPSI

Ig : Igneous

Sed : Sedimentary

Met : Metamorphic

Gr : Granite

Gn : Gneiss

Ss : Sandstone

Sch : Schist

Sh : Shale

Ls : Limestone

Qz : Quartz

M : Monzonite

Sts : Siltstone

Qe : Quartzite

Te : Tactite

He : Hematite

Me : Martite

Md : Mudstone

L : Laminated

Ma : Massive

J : Jointed

Hy : Highly

My : Moderately

Mr : Minor

PC : Poorly Cemented

O : Oscillator

Shld : Shield

Conv : Conventional

DWU : Dry Unit Weight, PCF

GW : Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	ROCK PROPERTIES										THRUST /SQ. FT.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	$f_c$	RQD	DW	HARDNESS*	SIZE, FT.	TUNNEL	KRF SPACE		
LAW-2	TBM	T-3	Sed=3	Ls	Ma	19	100	160	42	13.67 dia.	Dry=1	0.20	4.28	3"x 2"x 1/2"
LAW-3	TBM	T-3	Sed=3	Ls	Ma	19	100	160	42	13.67 dia.	Dry=1	0.20	4.28	3"x 2-1/2" x 1/2"
LAW-4	TBM	T-3	Sed=3	Ls	Ma	19	100	160	42	13.67 dia.	Dry=1	0.20	3.76	3-1/2"x 2-1/2" x 3/4"
COL. NO. 66		1	2			3	4	5	6		7	8	9	

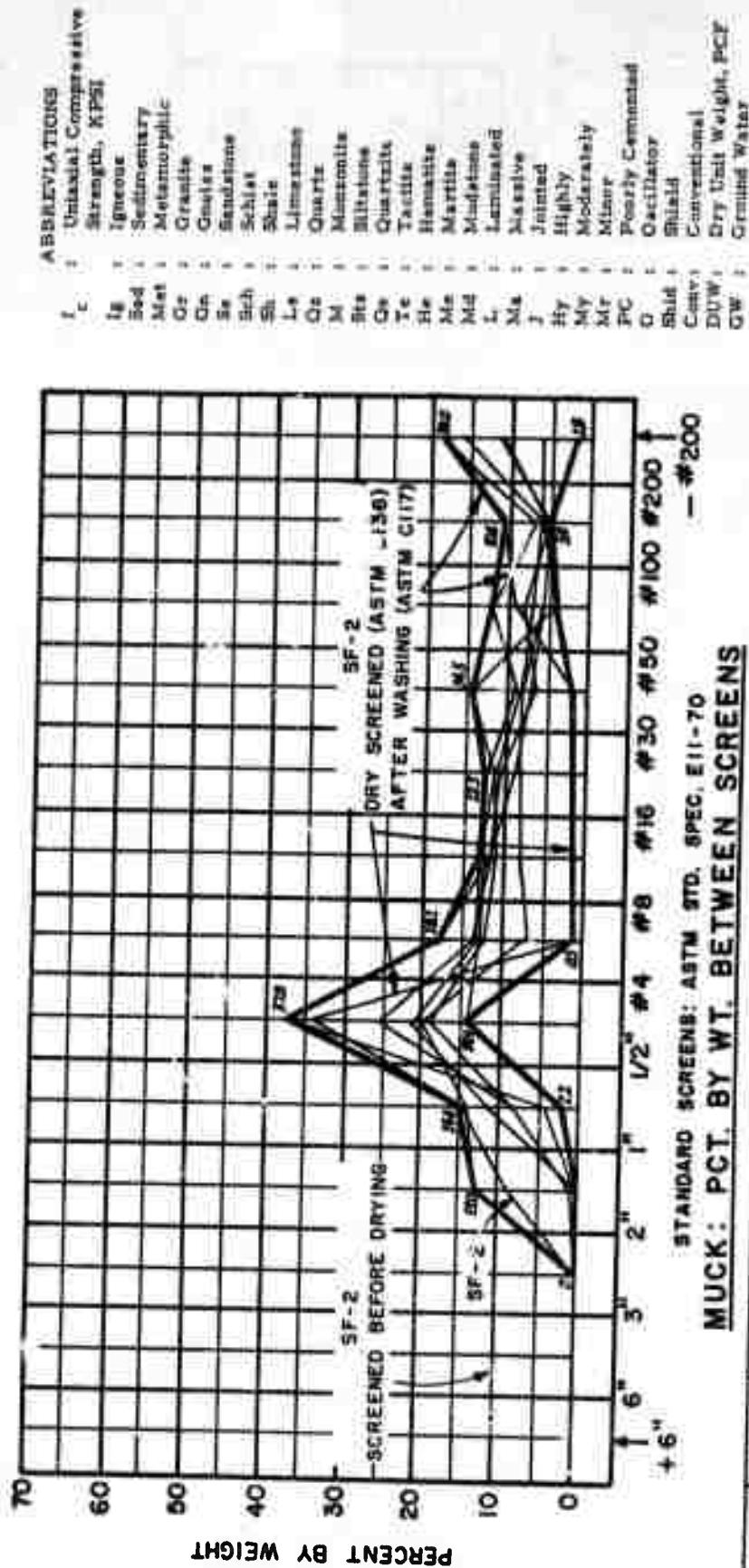
\*Inferred from D. U. Deere, et al, AD 646 610-1966.

\*\*Regression Data List.

FIGURE 3-7: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-3, MACHINE





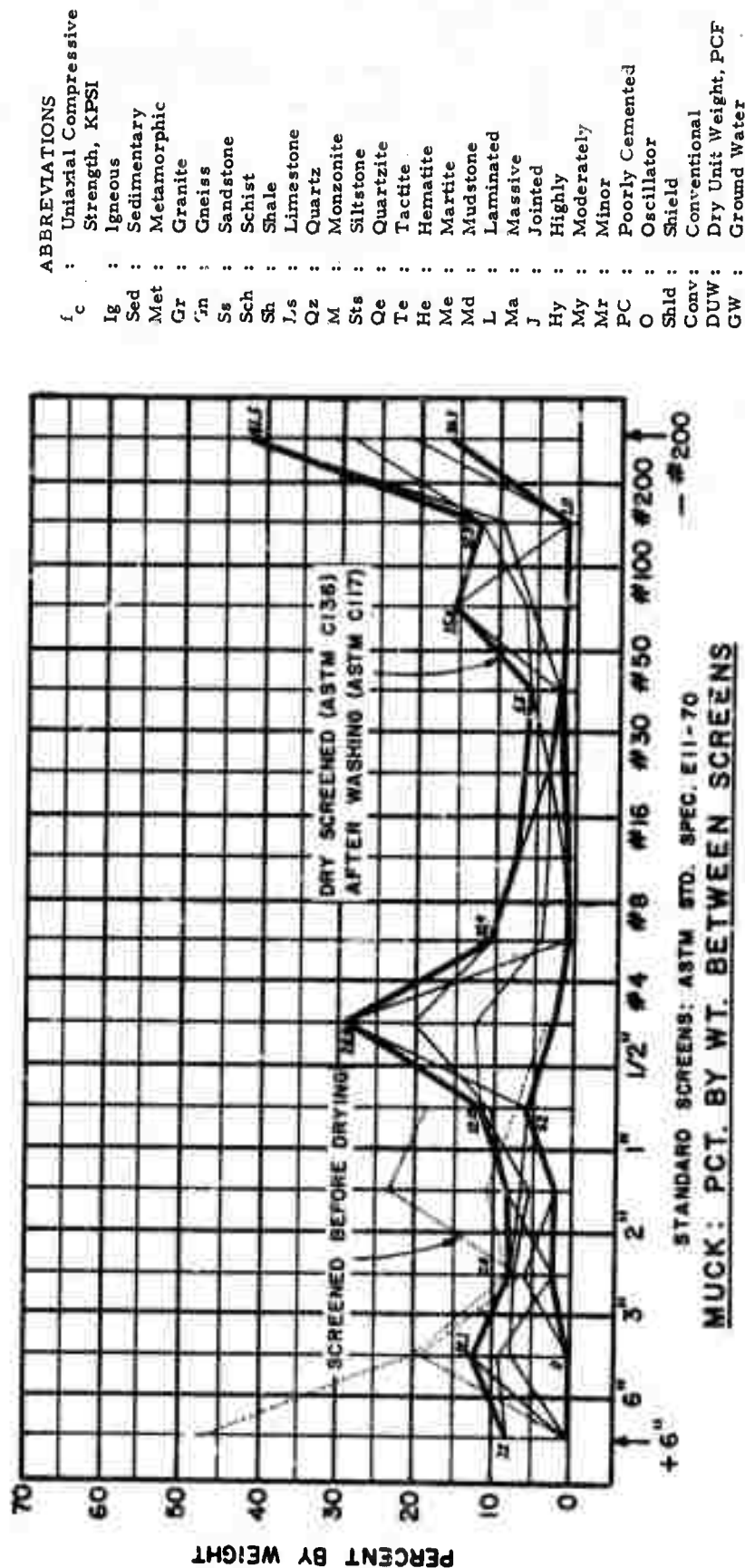


IDENT. NO.	EXCAV. METHOD	NDN	ROCK PROPERTIES										TUNNEL		KERF SPACE	THRUST /SQ. FT.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	f <sub>c</sub>	RQD	DUW	HARNESS <sup>a</sup>	SIZE, FT.	GW						
CL-1	TBM	T-5	Met-2	Gr-Gn	Hy J	9	10	174	45	13 dia.	2	0.09	5.09	1-1/2" x 2-1/2" x 3/4"			
SF-2	Shld	T-5	Sed-3	Ss	PC	2	50	142	30	21 dia.	3	NA	NA	3" x 2" x 8"			
NAST-1	TBM	T-5	Ig-1	Gr	My J	18	90	157	55	9.75 dia.	2	0.09	3.89	1" x 1" x 1/2"			
NAST-4	TBM	T-5	Ig-1	Gr	My J	24	90	160	55	9.83 dia.	2	0.09	8.45	1-1/2" x 1" x 1/2"			
LR-5	RBM	T-5	Ig-1	Gr-M	My J	12	92	165	55	12 dia.	1	0.24	4.46	2-1/2" x 4" x 3/4"			
LR-6	RBM	T-5	Ig-1	Gr-M	Hy J	7	86	137	50	4 dia.	1	0.13	17.20	2" x 3-1/2" x 1-1/4"			
NAST-1	TBM	T-5	Ig-1	Gr	My J	18	90	167	55	9.75 dia.	2	0.09	3.89	1" x 3/4" x 1/2"			
COL. NO. 66		1	2			3	4	5	6		7	8	9				

Inferred from D. V. Deers, et al., AD-646 610-1966.

Regression Data List.

FIGURE 3-9: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-5, MACHINE AND SHIELD



ABBREVIATIONS

f<sub>c</sub> : Uniaxial Compressive Strength, KPSI

Ig : Igneous

Sed : Sedimentary

Met : Metamorphic

Gr : Granite

Gn : Gneiss

Ss : Sandstone

Sch : Schist

Sh : Shale

Ls : Limestone

Qz : Quartz

M : Monzonite

Sts : Siltstone

Qe : Quartzite

Te : Tactite

He : Hematite

Me : Martite

Md : Mudstone

L : Laminated

Ma : Massive

J : Jointed

Hy : Highly

My : Moderately

Mr : Minor

PC : Poorly Cemented

O : Oscillator

Shld : Shield

Conv : Conventional

DUW : Dry Unit Weight, PCF

GW : Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	ROCK PROPERTIES							TUNNEL		KERF SPACE	THRUST /SQ. FT.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	f <sub>c</sub>	RQD	DUW	HARDNESS*	SIZE, FT.	GW			
KM-1	TBM	T-6	Sed=3	Md	Ma	11	90	144	40	10W x 9	Dry=1	NA	NA	36"x 14"x 8"
NB-1	TBM-O	T-6	Met=2	He Me	L Hy J	7	10	207	28	9.96 dia.	Dry=1	NA	NA	2'x 1-1/2'x 8"
LAY-1	TBM <sub>1</sub>	T-6	Sed=3	Ss	Ma	10	84	150	47	12.92 dia.	Dry=1	2.73	4"x 4"x 1/2"	
NAV-1	TBM	T-6	Sed=3	Sts	Ma	2	70	142	25	20.5 dia.	Dry=1	1.31	6"x 5"x 2"	
COL. NO. ***		1	2			3	4	5	6			8	9	

\*Inferred from D. U. Deere, et al, AD 646 610-1966.

\*\*Regression Data List.

FIGURE 3-10: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-6, MACHINE



Belt conveyor and hydraulic transportation parameters have been studied under the current program. Standard belt conveyor design publications and available literature on hydraulic conveying were reviewed to determine the data required and the methods used in system designs.

The parametric mathematical models described in HN-8080 "Materials Handling for Tunnels," referenced in Appendix E, were reviewed for application in this study. It is apparent that muck size and size distribution, on which MDN's are based, as well as other physical property characteristics determined in the program can be used as input for the design formulae and the models.

Modification and refinement of the models, originally developed for the high advance rates of the future, will be necessary for direct application to current operations. Some design parameters are not well defined in the references, and further study will be necessary to resolve differences in design philosophy which appear in the literature.

A preliminary design of a hydraulic muck disposal system based on data from a TBM tunnel is in process. Comparison between a design based on study data and an extensive suspended conveyor installation is planned. One example of MDN application to each of the other transport systems will be provided.

#### 4. DOD IMPLICATIONS

The data accumulated under the program are nonexistent in usable form elsewhere. While some TBM manufacturers and operators use muck size as an indicator of cutter efficiency, changes are noted during informal inspections at the machine and are seldom recorded except as showing a need for cutter replacement. A few screen analyses have been run, but results normally are not made available outside of a manufacturer's or contractor's organization.

Current selection of transportation systems usually is based on availability, intuition, and contractor familiarity with the equipment used at other sites. In some cases, the choice has been completely unsuitable for the muck produced. This has resulted in delays and additional expense which may be avoided by use of the information collected by the MDN study.

Previous investigations have indicated that major modifications of conventional equipment, or design of completely new systems, will be necessary to dispose of the muck from the high speed excavation systems predicted for the future. Muck characteristic data is a requisite as a basis for the engineering design of such system improvements or of innovative systems.

As an alternate to the design of a haulage system suitable for handling a particular muck, it may be practical to change muck characteristics at the face to provide a suitable feed for a handling system particularly well adapted to the tunnel site. MDN data will be invaluable to the selection of the necessary processing equipment.

A second alternate is in providing a continuous transport system such as hydraulic or pneumatic for the major volume of the muck, and temporary storage, as in a trailer or muck car, for a minor quantity of oversize which would be handled periodically. Again, muck characteristic data is a necessity to design the separation equipment and to estimate the capacity required in the secondary system.

In the course of the current program and subsequent use of the data produced, it is probable that potential improvements in transportation systems will appear. Where such improvements require the application of techniques which are technically sound but not developed to a point of practical application, they will be identified as attractive areas for research.

In summary, the current MDN program provides the basic data required for a rational, engineering approach to problem solutions in a most important subsystem of the rapid excavation process. It will show examples of data application and should be used to indicate the areas in which research and development of modifications or new methods would be most productive.

## 5. IMPLICATIONS FOR FURTHER RESEARCH

### 5.1 SAMPLE AND DATA COLLECTION

At the end of the current contract, it is expected that the following samples will have been collected, including 19 in 1972 and 1 collected but not tested in the 1971 program.

Excavation Method	Rock Strength					Total
	Very High	High	Medium	Low	Very Low	
Conventional	3	9	5	1	1	19
Shield	0	0	0	0	2	2
Machine						
Drag Cutters	0	1	1	2	1	5
Disc Cutters	2	7	5	1	0	15
Roller Cutters	0	4	1	0	0	5
Combination Cutters	0	3	1	1	2	7

At completion, the current program will have produced samples from 11 operations and/or formations which have not been sampled previously and which will be available for additional field work. To conform to good sampling and testing practice, the reliability of the data should be confirmed by repetition, preferably of all single tests.

While the major interest of the program is in strong rocks, variations in muck characteristics with strength can only be demonstrated by sampling the full range of rock strengths excavated by any one method. As they are available, additional sites should be sampled in formations of varied strength, such as the fine grained igneous and volcanic rocks.

Statistically, the number of samples used in developing a predictor equation should be greater than the number of the variables used in the analysis. Because the reliability of prediction is of major importance, additional samples should be obtained in the following operations:

1. Drag Cutter Machine excavation in High, Medium, and Low Strength rocks. These samples would provide a confirming data set in each strength category, and a total number of samples larger than the number of variables.



2. Roller Cutter Machine tunneling to provide enough data to analyze this method by a separate regression.
3. Combination Cutter Machine excavation in Low Strength rock to confirm data from a single sample collected previously.
4. Conventional tunneling in Low and Very Low Strength rocks to confirm data from single samples collected previously.
5. Disc Cutter Machine tunneling in Low Strength formations to improve the spread of the data on this method.
6. Disc Cutter Machine tunneling with tungsten carbide button insert cutters as a promising development in machine excavation of strong rocks.

## 5.2 PHYSICAL TESTING

Although problems have been encountered in obtaining consistent results from Schmidt hardness tests on core samples, development of test methods should continue because it is the only fast and inexpensive known test to measure the property of rocks.

Abrasiveness testing should be initiated as soon as possible and continued within the limit of available funds to provide data for the cost analysis phase of equipment selection.

The modified Protodyakonov test for resistance to fragmentation should be investigated for effectiveness and cost to evaluate development of data on this rock property for use in regression analysis and prediction of MDN's.

## 5.3 INNOVATIVE TECHNIQUES

Unusual rock breaking techniques now under development, such as the electron beam, the water cannon, the conical borer, and continuous application of explosives may become standard practice in the future. Sampling muck from tests of these methods whenever possible is recommended.

## 6. SPECIAL COMMENTS

A Schmidt rebound hardness tester and two MSA self-rescuers were purchased for use in the current program. No invention has been made in the course of the work performed under this contract.

## GLOSSARY

ASTM	American Society for Testing and Materials	PF	Powder Factor
BM	Beam	PMSRC	Pittsburgh Mining and Safety Research Center
CFM	Cubic feet per minute	POT.	Potential
CNTR	Center	PSF	Pounds per square foot
COMPR.	Compressed	PSI	Pounds per square inch
CONTIN.	Continuous	Rect.	Rectangular
CONV	Conveyor	REG.	Regular
CY	Cubic Yard	RBM	Raise Boring Machine
DEG.	Degrees	RPM	Revolutions per Minute
DIA.	Diameter	RQD	Rock Quality Designation
DUW	Dry Unit Weight	SF	Square Foot
Est, (E)	Estimated	ST	Scoop Tram
FWD	Four Wheel Drive	SPECIF.	Specific
GPM	Gallons per Minute	STRNTH.	Strength
HP	Horse Power	TBM	Tunnel Boring Machine
HRS.	Hours	TC	Tungsten Carbide
IN.	Inch	TCB	Tungsten Carbide Button
INTEG	Integral	T	Tentative
Inter.	Internal	T.	Ton
K	Thousand	V	Volt
LBS, #	Pounds	VOL	Volume
LHD	Load Haul Dump	W/	With
LT	Long Ton	WT.	Weight
MDN	Muck Designation Number	'	Foot
MAX	Maximum	"	Inch
Moist.	Moisture	#	Number
MM	Millimeter	%	Percent
NA.	Not Available	(+)	Plus
NO.	Number	(-)	Minus
PCF	Pounds per Cubic Foot		
PCT	Percent		

APPENDIX A  
TUNNEL PROJECTS

Compiled by Holmes & Narver, Inc., Anaheim, California, under U. S.  
Bureau of Mines Contract H0220023. Revised September 1, 1972

NORTH AMERICAN CONTINENT

<u>Project and Location</u>	<u>Owner or Agency</u>	<u>Size</u>	<u>Length</u>	<u>Contractor</u>
Lakeshore Mine Casa Grande, Arizona	Hecla Mining Co. El Paso Natural Gas	14'x14' 14'x18' Plus Level Development	7,500'	Hecla Mining Company Own Force

The two 7,500' headings, declines at a minus 15°, are nearing completion. Levels are being developed at 900' and 1,400' vertically below the portal. Formations include mylonite, quartzite, tactite, and quartz monzonite. A raise boring machine has started a series of holes to the development levels.

Superior Mine Superior, Arizona	Magma Copper Company	10'x10'	Various	Own Force
---------------------------------------	-------------------------	---------	---------	-----------

Drifting on five levels to connect existing workings with a new shaft, now within 300' of completion at 4,200' depth. Formations are cretaceous conglomerate 7K to 10K psi, limestone 7K psi, quartzite to 20K psi. Operations are conventional.

San Manuel Mine San Manuel, Arizona	Magma Copper Company	12'x12'	Various	Own Force
---	-------------------------	---------	---------	-----------

Main level drifting on two levels in quartz monzonite and monzonite porphyry, concurrent with shaft sinking to 3,700' depth. A 9,000' drift is planned to explore a new ore body from the bottom level of the new shaft.

Tonner #1 and #2 Brea, Calif.	The Metropolitan Water District of Southern Calif.	11'6" Diameter	#1 - 4,589' #2 -19,360'	Shea Construction Company
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A Calweld machine is being assembled at the site to bore low strength sandstone and siltstone. Geologic data and cores are available from the owner agency.

<u>Project and Location</u>	<u>Owner or Agency</u>	<u>Size</u>	<u>Length</u>	<u>Contractor</u>
Hunter Tunnel Fryingpan Project Merideth, Colorado	U.S. Bureau of Reclamation Denver, Colorado	10'x10'	4.4 Miles	Granite Construction Company

A conventional operation in formations similar to the Nast tunnel. Lithologic and engineering property data have been collected from the U. S. Bureau of Reclamation. Excavation is scheduled for completion in October, 1972.

Nast Tunnel Fryingpan Project Merideth, Colorado	U.S. Bureau of Reclamation Denver, Colorado	10' Diameter	3 Miles	Peter Kiewit Sons Company
---	--	-----------------	---------	---------------------------------

A Wirth boring machine has been replaced by conventional drifting in fault zones, and is scheduled to resume work in more competent rock in November, 1972. Formations are predominantly granite, granite gneiss, granite porphyry, and granodiorite with compressive strengths from 18K to 24K psi. Rock is highly sheared in zones from a few feet to 400' thick.

Foggy Bottom Rosslyn Tunnel Section C-4 Washington, D.C.	WMATA Washington, D. C.	16'8" Diameter Finished	4,000' Each of Two Bores	Shea-Ball- S&M Construction J. V.
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Excavation by conventional methods in gneiss under the Potomac River. The schistose rock structure is reported to result in high shear strength and low compressive strength. Lithologic and engineering property data has been collected from the WMATA.

Crescent Mine Osburne, Idaho	Bunker Hill Company Kellogg, Idaho	10'x10'	Various	Own Force
---------------------------------	--	---------	---------	-----------

Conventional drifting on several levels. Trackless equipment is used on the lowest level, at 6,100' depth in quartzite, from which a lower level will be developed by a decline. The USBM Spokane Mining Research Center has collected voluminous rock property data at this site.

<u>Project and Location</u>	<u>Owner or Agency</u>	<u>Size</u>	<u>Length</u>	<u>Contractor</u>
Star Mine Burke, Idaho	Hecla Mining Company, Wallace, Idaho	9'x10'	Various	Own Force

Conventional drifting on several levels. Rail mounted equipment is in use on the lowest level, at 7,094' depth, in quartzite.

Mt. Greenwood Tunnel Chicago, Illinois	Dept. of Public Works, City of Chicago, Illinois	10'4" Diameter	1.8 Miles	S. A. Healy Construction Company
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A Robbins machine has finished Mt. Greenwood No. 1. Preparations are in progress to start Mt. Greenwood No. 2 in limestone, reported similar to that in the Mt. Greenwood No. 1. Geologic and rock data has been collected from the owner agency.

White Pine Copper Company White Pine, Michigan	Copper Range Company New York, New York	18'1" Diameter 18'x8-1/2' Rectangular	Various	Tunneling by White Pine With Own Force
---	--	--	---------	---

A Robbins machine, operating in sandstone since 1969, has passed through a conglomerate horizon into the overlying shale. An Atlas-Copco machine is operating in the shale. Normal drifting is conventional. Existing rock property data includes compression, Brazilian tensile, and Shore hardness test results.

Nevada Test Site Mercury, Nevada	USAEC and Defense Atomic Support Agency (DASA) Mercury, Nevada	Various	Various	Reynolds Electrical and Engineering Company
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Conventional and Alpine Miner tunnels may provide an opportunity for comparison of the muck produced by the two systems. Formations are volcanic tuffs which vary from 600 to 4,500 psi in unconfined compressive strength. Engineering property data has been collected by the U. S. Geological Survey and by DASA.

<u>Project and Location</u>	<u>Owner or Agency</u>	<u>Size</u>	<u>Length</u>	<u>Contractor</u>
Navajo Irrigation Project Farmington, New Mexico	U.S. Bureau of Reclamation Denver, Colorado	20.5' Diameter	3 Miles	Fluor-Utah Engineering & Construction Company

A Dresser boring machine is operating in sandstone with an unconfined compressive strength of less than 1K psi, and is expected to reach a 9.7K psi sandstone as the tunnel advances. Completion is scheduled for November, 1972.

Section 35 Uranium Mine Grants (Ambrosia Lake), New Mexico	Kerr-McGee Corporation	10'x10' and 8'x8'	Various	Kerr-McGee Own Force
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An Alpine Miner is operating in sandstone development headings, in which normal operations are conventional.

Kermac Potash Carlsbad, New Mexico	Kerr-McGee Corporation	13'x5'	Various	Own Force
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Goodman continuous miners are operating in salt-potash formations reported from 3K to 6K psi in strength.

Cross-Irondequoit Interceptor Tunnel, Rochester, New York	Dept. of Public Works, Rochester, New York	18'4" Diameter	5-1/2 Miles	Tunnel Constructors (Greenfield-Ferrera-S.A. Healy, J. V.)
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A Lawrence TBM is operating in formations reported as shale, limestone, and sandstone, compressive strengths 2K to 20K psi. Geologic and rock data has been collected from the owner agency.

<u>Project and Location</u>	<u>Owner or Agency</u>	<u>Size</u>	<u>Length</u>	<u>Contractor</u>
New York City, New York Contract #13	Dept. of Public Works, New York, New York	11'6" and 8'6"	9,200'	Perini-B&R- G.H. Ball- S&M Constructors, J. V.

Two Jarva TBM's are operating in mica schist, with compressive strength reported 15K to 30K psi. Cores and rock test data are available from the owner.

Homestake Mine, Lead, South Dakota	Homestake Mining Company	7-1/2'x 8-1/2'	Various	Own Force
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Conventional main level development drifting at 150' vertical intervals to 7,100' depth in phyllites, quartz mica schists, quartzites, carbonates and silicates, ranging in strength from 5K to 40K psi.

Cross Town Wastewater Interceptor Austin, Texas	City of Austin, Texas	9' Diameter 10' Diameter	27,300'  30,500'	Granite Constr. Co. Peter Kiewit & Sons Company
--	--------------------------	-----------------------------------	------------------------	--

A Calweld machine will bore 30,500' in clays and limestones. A Robbins machine will bore 27,300' in limestones. Geologic and test data has been provided by the City of Austin.

Currant and Layout Tunnels Strawberry Aqueduct Heber City, Utah	U.S. Bureau of Reclamation Denver, Colorado	10'4" Diameter	Combined Length 4.9 Miles	S. A. Healy Construction Company
---	---	-------------------	---------------------------------	--

The Layout tunnel has been completed. A Robbins boring machine has started the Currant tunnel in conglomerate. Existing logs of drill holes show lithology. Compressive strength test results, from 14K psi to over 38K psi in the conglomerate, have been provided by the Bureau of Reclamation.



<u>Project and Location</u>	<u>Owner or Agency</u>	<u>Size</u>	<u>Length</u>	<u>Contractor</u>
Golden Goose II Uranium Mine Jeffrey City, Wyoming	Western Nuclear, Inc.	8' x 10'	Develop- ment Drifts	Owner Operated

An Alpine Miner equipped with a Serpentix conveyor is driving mining headings in soft sandstone. Conventional drifts are also being driven in similar formations.

Matheson "B" Mine	Cleveland Cliffs Iron Company Ishpeming, Michigan	10' x 10'	Various	Own Force
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Conventional timbered and untimbered development drifting on the 12th level in graywacke at 3,480' depth, conventional and Alpine Miner stope development in iron formation and ore above main levels.

APPENDIX B  
RAW DATA SHEETS

<u>Identification</u>	<u>Page</u>	<u>Identification</u>	<u>Page</u>
NAST-1	B-1, B-2	5-1	B-51, B-52
NAST-2	B-3, B-4	7-2	B-53, B-54
NAST-3	B-5, B-6	11-3	B-55, B-56
NAST-4	B-7, B-8	11-4	B-57, B-58
GA-1	B-9, B-10	72-1	B-59, B-60
H-1	B-11, B-12	MSU-1	B-61, B-62
H-2	B-13, B-14	MSU-2	B-63, B-64
LK-1	B-15, B-16	LAW-2	B-65, B-66
LK-2	B-17, B-18	LAW-3	B-67, B-68
LK-5	B-19, B-20	LAW-4	B-69, B-70
LK-6	B-21, B-22	MIL-1	B-71, B-72
LK-7	B-23, B-24	MIL-2	B-73, B-74
SM-1	B-25, B-26	MIL-3	B-75, B-76
CL-1	B-27, B-28	EVG-1	B-77, B-78
LK-3	B-29, B-30	EVG-2	B-79, B-80
LK-4	B-31, B-32	LAY-1	B-81, B-82
MB-1	B-33, B-34	LAY-2	B-83, B-84
MB-3	B-35, B-36	NAV-1	B-85, B-86
ST-1	B-37, B-38	NAV-2	B-87, B-88
CR-1	B-39, B-40	RO-1	B-89, B-90
HS-1	B-41, B-42	WNG-1	B-91, B-92
NY-1	B-43, B-44	WNG-2	B-93, B-94
NY-2	B-45, B-46	SF-1	B-95, B-96
QL-1	B-47, B-48	SF-2	B-97, B-98
MB-2	B-49, B-50	KM-1	B-99, B-100

B-i

**APPENDIX B**  
**RAW DATA SHEETS**

*B-ii*

KEY IDENTIFICATION

ROCK PROPERTIES

IGNEDUS: GRANITE, GRAY, MEDIUM  
TO FINE GRAINED, MODERATELY TO  
SLIGHTLY FRACTURED AND JOINTED  
10 TO 20 PCT QUARTZ. 50 TO 60  
PCT FELDSPAR, BALANCE DARK  
MINERALS.

DRY WT PCF 167  
COMPR STRNTH KPSI 18  
RQD PCT EST. 90  
SHAPE MOH SCHMIDT NA NA NA

HARNESS.....  
PCT EST. 90  
SHAPE MOH SCHMIDT NA NA NA

MUCK DATA

DRY UNIT WT PCF 83  
MOISTURE PCT 9.4  
IN-SIZE 0.0  
PCT 0.0  
0.0  
0.0  
0.0  
0.0  
2.2  
14.9  
12.5  
12.4  
12.3  
8.6  
11.8  
6.8  
18.5  
PCT (-) NO200 NO100 NO50 NO30 NO16 NO8 NO4

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

POT VOL CHANGE (-) 10.065 IN-SIZE

LIQUID LIMIT PCT 14.50  
PLASTIC LIMIT PCT 14.00  
SHRINKAGE LIMIT PCT 13.50  
ATTEMPTED LIMITS..SIZE(-) 0.185IN..  
PLASTICITY INDEX PCT 0.50  
FLOW INDEX 3.0  
TOUGHNESS INDEX 0.16

(-) 0.50IN-SIZE SPECIF GRAVITY

ANGLE/REPOSE 1 IN DROP 9.0 PCT MOIST 37  
ANGLE/REPOSE 10 IN DROP 9.0 PCT MOIST 36  
ANGLE/REPOSE 10 IN DROP 9.0 PCT MOIST 41  
MATERIAL SIZE(-) 0.50 IN..  
ANGLE/REPOSE 10 IN DROP 9.0 PCT MOIST 41  
ANGLE/REPOSE 10 IN DROP 9.0 PCT MOIST 42  
APPARENT COHESION PSF AT PCT MOIST NA  
BUK COHESION PSF AT PCT MOIST NA  
SIZE(-) 0.185 IN. ANGLE INTER FRICTION DEGREES AT 8.5 PCT MOIST

NAST-1 CURRENT: 1 SEPT. 1972

## KEY

1A  
TUNNEL DATA

TUNNEL	VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE 9FT. 9IN.	SHAPE ROUND	GRADE +0.22PCT 10K	CFM 10K	PRESS EXHST X	SIZE 22IN	HP	GPM 5-20	AIR WATER PUMP 6IN 2IN 6IN
								PRIMARY 4160V
								SECONDARY 480V

## HAULAGE SYSTEM

MUCK RAIL, 36IN  
GAGE, 70LB  
RAIL, 16 CY  
CARS  
MOTOR 12 TON

## SUPPORT SYSTEM

BULT. TYPE SIZE  
4-11N X 7FT  
GROUTED

SET, SIZE, SHAPE  
4IN RING AND HALF  
SETS 4F1, 3F1, AND  
2FT IN BAD GROUND

## SHOTCRETE

## MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM., CUTTING EDGES		RPM	TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MAKE WIRTH ERKELFENZ	MODEL HARPOCK	WT 67 TONS	CENTER 2 HUGHES/4IRTH TCB 11.5IN ROLLER 2-TCB 11.5IN TCB CONE	INTERIOR 15 HUGHES/4IRTH TCB 11.5IN ROLLER	GAGE 6 HUGHES/4IRTH TCB 11.5IN TCB MOLLER	HEAD 8.5 INTEG	CENTER KFTLB 150 KFTLB 110 KFTLB 290

ANCHOR PRESS MUCK SYSTEM  
BUCKET FROM  
FACE, 22IN  
CONVEYOR TO  
REAR

POWER SYSTEM  
HYDRAULIC,  
POWERED BY  
3-200HP MOTORS

GUIDANCE THRU/SQ FT

LASER KLB 3.89

## CONVENTIONAL EXCAVATION

MACHINE JUMBO  
MACHINES

ROUND, NO. HOLES  
DEPTH  
DIAM.  
CUT.

FEED LENGTH

EXPLOSIVES,  
POWDER FACTOR  
TOTAL LBS  
PRIMERS,  
TRIM  
INTERIOR  
CUT  
LIFTERS

BLASTING

MUCKING

GUIDANCE

NAST-1

CURRENT: 09/01/72

**ROCK PROPERTIES  
IGNEOUS: GRANITE  
TO FINE GRAINED,  
SLIGHTLY FRACTURED  
10 TO 20 PCI QUARTZ  
PCI FELDSPAR HAL  
MINERALS.**

COMPR	STATH	R00	SHORE	HARDNESS
KPSI	PCT	EST	MOH	MOH
18	90	NA	NA	NA

ORY  
WT  
PCF

167

	PCT (•)16	PER CENT BY WEIGHT	BETWEEN SCREENS.....*	PCT (-)16
	IN SIZE	6IN. 3IN. 2IN. 1IN. 1/2IN. NO4	NO8 NO16 NO30 NO50 NO100 NO200	NO200
MOISTURE				
PCT				

	10.8	0.0	0.0	0.0	0.8	8.0	25.0	13.8	11.5	10.3	6.6	7.7	5.5	10.8
76	10.8	0.0	0.0	0.0	0.8	8.0	25.0	13.8	11.5	10.3	6.6	7.7	5.5	10.8

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES    A=ANGULAR   S=SUBANGULAR   R=ROUNDED   P=PLATY   C=CUBIC   I=IRREGULAR   E=ELONGATEO   SP=SPHEROID

POT VOL CHANGE  
(-) 0.056 IN. SIZE

	.....ATTENBERG LIMITS.....SIZE(-) 0.056IN.....							
	PLASTIC SHINKAGE		PLASTICITY		FLOW INDEX		TOUGHNESS INDEX	
	LIMIT PCT	LIMIT PCT	LIMIT PCT	PCT	INDEX	INDEX		
LIQUID LIMITS								

	0	19.5	18.2	17.9	1.3	4.6	0.28
0							

(-) 0.50 IN. SIZE SPECIFIC GRAVITY		*..... MATERIAL SIZE (-) 1.0 IN. ....*		SIZE (-) 1.0 IN.	
ANGLE/REPOSE	ANGLE/REPOSE	ANGLE/SLIDE	APPARENT	BULK	ANGLE INTER
I IN DROP	10 IN DROP	STEEL PLATE	COHESION	DENSITY	FRICTION
DEGREES AT	DEGREES AT	DEGREES AT	PSF AT	PCF AT	DEGREES AT
8.7 PCT MOIST	8.7 PCT MOIST	8.7 PCT MOIST	PCT MOIST	PCT MOIST	8.5 PCT MOIST

	38	38	49	NA	NA	31
2.66						

MAST-2 CURRENT: 1 SEPT. 1972

## KEY

2A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	WATER PUMP
9FT	ROUND	+0.22PCT	10K		X	22IN		5-20	6IN 2IN 6IN
9IN									
HAULAGE SYSTEM		PERSONNEL		SUPPLY		SUPPORT SYSTEM		SHOTCRETE	
MUCK	RAIL, 36IN								
GAGE	70LB								
RAIL, 16									
CY CARS									
MOTOR	12 TON								
MACHINE EXCAVATION		CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES		RPM		TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MACHINE									
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD, CENTER	HEAD	CENTER	
4IRTH	HARROCK	67	2 HUGHES/WIRTH	15 HUGHES/WIRTH	6 HUGHES/WIRTH	8.5' INTEG	KFTLB 150	KFTLB 8	KL8
ERKELENZ		TONS	TCB 11.5IN	TCB 11.5IN	TCB 11.5IN		KFTLB 110	KFTLB	KL8 290
			POLLER, 2-TCB	ROLLER	ROLLER				
			11.5IN CONE						

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/50 FT
KL8	BUCKETS FROM	HYDRAULIC,	LASER	KLH 3.89
	FACE, 22IN	POWERED BY		
	CONVEYOR TO	3-200HP MOTORS		
	REAR			

## CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES	EXPLOSIVES,	BLASTING	MUCKING	GUIDANCE
JUMRO	DEPTH	POWDER FACTOR			
MACHINES	DIAM.	TOTAL LBS			
	CUT,	PRIMERS,			
		THIN			
		INTERIOR			
		CUT			
		LIFTERS			

## FEED LENGTH

KEY IDENTIFICATION  
3 NAST  
SAMPLE NO  
NAST-3

ROCK PROPERTIES  
IGNEOUS: BIOTITIC GRANITE FINE  
GRAINED, MAJOR QUARTZ, MINOR  
FELDSPAR AND DARK MINERAL  
CONTENT.

DRY WT PCF 152  
COMPR STRNTH K'SI 13  
ROD PCT EST 90  
SHORE MDH SCHMIDT NA  
HARDNESS NA

MUCK DATA  
DRY UNIT  
JT PCF 117  
MOISTURE PCT 3.4  
PCT 14.5  
IN-SIZE 16.2 6.2 12.6 13.7 8.9 5.8 5.3 6.1 2.6 2.8 1.5  
PCT (-) NO200 3.8

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

AI AI AI AI AI AI AI AI AI AI AI AI AI AI AI

POT VOL CHANGE (-) 0.056 IN-SIZE  
LIQUID LIMITS PCT 19.50  
PLASTIC LIMIT PCT 17.41  
SHRINKAGE LIMIT PCT 17.13  
PLASTICITY INDEX PCT 2.63  
FLOW INDEX 4.10  
TOUGHNESS INDEX 0.51

(-) 0.75IN-SIZE SPECIFIC GRAVITY  
ANGLE/REPOSE 1 IN DROP DEGREES AT 2.8 PCT MOIST  
ANGLE/SLIDE STEEL PLATE DEGREES AT 2.8 PCT MOIST  
MATERIAL SIZE (-) 2.0 IN  
ANGLE/REPOSE 10 IN DROP DEGREES AT 2.8 PCT MOIST  
APPARENT COHESION PSF AT 3.0 PCT MOIST  
BULK DENSITY PCF AT 0.0 PCT MOIST  
SIZE (-) 2.0 IN. ANGLE INTER FRICTION DEGREES AT 3.0 PCT MOIST

2.65 39 36 31 80 91.2 38

NAST-3 CURRENT: 1 SEPT. 1972



KEY

3A  
TUNNEL DATA

TUNNEL			VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS EXHST	SIZE	HP	GPM	AIR WATER FUME	PRIMARY	SECONDARY
10FT X 16FT	ALCOVE	0.0	10K	X	22IN		5-10	6IN 2IN 6IN	NA	NA
HAULAGE SYSTEM										
MUCK			PERSONNEL			SUPPLY			SUPPORT SYSTEM	
RAIL 35IN GAGE, 70LB RAIL, 16 CY CARS			RAIL			RAIL			SHOTCRETE	
MOTOR 12 TON										
			BOLT TYPE SIZE			ROOF PLATE			SET SIZE SHAPE	
			1IN X 7FT			13IN X 10FT			NA	
			GROUTED			16 GAGE				

MACHINE EXCAVATION

MACHINE	MAKE	MODEL	WT	CUTTERS MAKE TYPE DIAM CUTTING EDGES	RPM	TORQUE MAX/OPERATE	THRUST MAX/OPERATE
				CENTER		HEAD CENTER	CENTER
				INTERIOR		KFTLB KFTLB	KLB KLB

ANCHOR PRESS MUCK SYSTEM POWER SYSTEM GUIDANCE THRU/50 FT

KLB

CONVENTIONAL EXCAVATION

MACHINE	ROUND	NO. HOLES	DEPTH	DIAM	CUT	DOUBLE V	SF/HOLE	EXPLOSIVES	POWDER FACTOR	6.3LB/CY	TOTAL LBS	300 GELEX 2, 60PCT	PRIMERS	TRIM	INTERIOR	CUT	LIFTERS	BLASTING	ELECTRICAL	0-7 REGULAR	DELAYS	MUCKING	1/2CY DIESEL	FRONT END	LOADER	GUIDANCE
JUN80		72	9FT	1-3/4IN			2.2																			
MACHINES	JACK	LEG	2-553F																							
FEEO	LENGTH	4FT																								

KEY IDENTIFICATION 4 NAST  
 SAMPLE NO NAST-4  
 ROCK PROPERTIES  
 IGNEOUS, GRANITE, FINE GRAINED  
 MODERATELY FRACTURED, MAJOR  
 QUARTZ AND MINOR FELDSPAR  
 CONTENTS.

ORY WT PCF 160  
 COMPR STRNTH KPSI 24  
 RQD PCT EST 90  
 SHORE MOH NA  
 HARDNESS NA  
 SCHMIDT NA

MUCK DATA  
 DRY UNIT WT PCF 83  
 MOISTURE PCT 17.2  
 IN-SIZE 0.0  
 6IN. 0.0  
 3IN. 0.0  
 2IN. 0.0  
 1IN. 11.5  
 NO4 20.6  
 NO8 13.6  
 NO16 12.7  
 NO30 11.0  
 NO50 14.5  
 NO100 4.4  
 NO200 5.8  
 PCT (-) NO200 5.9

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATE C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

P:

PI

PI

PI

PI

PI

PI

PI

POT VOL CHANGE (-) 0.056 IN-SIZE  
 LIQUID LIMIT PCT 19.20  
 PLASTIC LIMIT PCT 18.97  
 SHRINKAGE LIMIT PCT 17.50  
 ATTERBERG LIMITS SIZE (-) 0.056 IN.  
 PLASTICITY INDEX PCT 0.23  
 FLOW INDEX 3.40  
 TOUGHNESS INDEX 0.06

(-) 0.75 IN-SIZE SPECIFIC GRAVITY  
 ANGLE/REPOSE 1 IN. DROP DEGREES AT 6.0 PCT MOIST  
 MATERIAL SIZE (-) 12.0 IN.  
 ANGLE/REPOSE 10 IN. DROP DEGREES AT 6.9 PCT MOIST  
 STEEL PLATE DEGREES AT 6.9 PCT MOIST  
 APPARENT COHESION PSF AT 7.1 PCT MOIST  
 BULK DENSITY PCF AT 0.0 PCT MOIST  
 SIZE (-) 12.0 IN. ANGLE INTER FRICTION DEGREES AT 7.1 PCT MOIST

2.64 39 34 40 0 91 33

NAST-4 CURRENT: 1 SEPT. 1972

KEY

4A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM					
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR	WATER	PUMP	PRIMARY	SECONDARY
9FT	ROUND	+0.22PCT	10K		A	22IN		5-20	6IN	2IN	6IN	4160V	480V
10IN													
HAULAGE SYSTEM		PERSONNEL		SUPPLY		SUPPORT SYSTEM		SET SIZE SHAPE		4IN RING AND HALF		SHOTCRETE	
MUCK	RAIL, 34IN												
GAGE, 70L/3													
RAIL, 16 CY													
CARS													
MOTOR 12 TONS													

MACHINE EXCAVATION

MACHINE		CUTTERS, MAKE, TYPE, DIA, CUTTING EDGES		RPM		TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MA/E	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD, CENTER	HEAD	CENTER	
WIRTH	HARDROCK	67	2 HUGHES TCR	14 HUGHES TCR	6 HUGHES TCR	8.5	INTEG	KFTLB	
ERKELENZ		TONS	11.5IN ROLLER,	11.5IN ROLLER	11.5IN ROLLER			KFTLB 150	KLB
HUGHES			2-11.5IN CONE					KFTLB 125	KFTLB
HEAD									KLB 630

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KL8	RACKET FROM	HYDRAULIC	LASER	
	FACE, 22FT	POWERED BY		KLB 8.45
	CONVEYOR TO	3-250HP MOTORS		
	REAR			

CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES	EXPLOSIVES, POWDER FACTOR	BLASTING	MUCKING	GUIDANCE
JUMBO	DEPTH	TOTAL LBS			
MACHINES	DIA, CUT,	TRIM			
		INTERIOR			
		CUT			
		LIFTERS			

KEY IDENTIFICATION 5 GRANITE ADIT

ROCK PROPERTIES

IGNFOUS: GRANITE, MASSIVE,  
MAJOR QUARTZ AND FELDSPAR,  
MINOR OAR. MINERAL CONTENT.

SHORE MOH SCHMIDT

COMPR STIRNTH

PCF

161 35 96 NA NA NA

MUCK DATA

DRY UNIT WT PCF

MOISTURE PCT(+16

IN-SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200

PCT (-) NO200

114 1.9 4.7 17.9 12.2 10.3 11.7 14.4 6.6 5.6 5.6 3.7 3.6 0.2 3.5

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

AI AI AI AI AI AI AI AI AI AI AI AI AI AI

POT VOL CHANGE (-)10.056 IN-SIZE

LIQUID LIMITS PCT

16.2 15.78 13.67 0.42 3.00 0.14

PLASTIC LIMIT PCT

10.056 IN-SIZE

SHRINKAGE LIMIT PCT

0.056 IN-SIZE

PLASTICITY INDEX PCT

TOUGHNESS INDEX

(-)10.75 IN-SIZE \* SPECIF GRAVITY

ANGLE/REPOSE 1 IN DROP DEGREES AT 0.9 PCT MOIST

ANGLE/REPOSE 10 IN DROP DEGREES AT 0.9 PCT MOIST

ANGLE/SLIDE STEEL PLATE DEGREES AT 0.9 PCT MOIST

APPARENT COHESION PSF AT 0.9 PCT MOIST

BULK DENSITY PCF AT 0.9 PCT MOIST

SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 0.9 PCT MOIST

2.59 35 36 34 215 106 46

GA-I CURRENT: 1 SEPT. 1972

## KEY

SA  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR
10FT X	MORSESHOE	-0.22PCT	8K		X	22IN			WATER PUMP
10FT									6IN 2IN
HAULAGE SYSTEM		SUPPORT SYSTEM		SET SIZE, SHAPE		SHOTCRETE		PRIMARY SECONDARY	
MUCK	PERSONNEL	SUPPLY	HOLI, TYPE	SIZE	ROOF	PLATE			110V
EIMCO 912 LMD	NONE	EIMCO 912	11IN X	7FT					
DIESEL		LMD DIESEL	GROUTED	APPROX					
				35FT					

## MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
MAKE	MODEL	WT	CENTER	INTERIOR
			GAGE	
			KFTLB	KFTLB
			KFTLB	KFTLB
			KLB	KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/50 FT
KLB				KLB

## CONVENTIONAL EXCAVATION

MACHINE	ROUND,	NO. HOLES	48	BLASTING	MUCKING	GUIDANCE
JUNBO CRAWLER		DEPTH	8FT	ELECTRICAL	EIMCO 912	LHD TRANSIT
MACHINES 2-D93 DRIFTER		DIAM.	1-3/4IN	0-10 REGULAR	FRONT END	
		CUT,	DOUBLE V	DELAYS	LOADER	
FEED LENGTH 10FT						
		SF/HOLE	2.1			
		LIFTERS				

GA-1 CURRENT: 09/01/72

KEY IDENTIFICATION  
6 HUNTER

SAMPLE NO  
H-1

ROCK PROPERTIES  
IGNEOUS: GRANITE, GRAY, FINE  
GRAINED, MODERATELY JOINTED,  
WITH 1.5 TO 2 FT BANOS OF  
LIGHT TAN PEGMATITE AND  
LAMINATED GRANITIC GNEISS.

ORV  
WT PCF 163  
COMPR  
STRNTH  
KPSI 32  
RQD  
PCT EST 80  
SHORE  
MOH NA  
HARDNESS  
SCHMIDT NA

MUCK DATA  
OPY UNIT  
WT PCF

MOISTURE PCT(+)16  
IN.SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NOS0 NO100 NO200 PCT (-)  
NO200  
3.4 14.2 6.0 12.7 13.2 13.6 12.9 5.7 4.3 4.1 3.0 3.8 2.2 3.4

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

AI AI AI AI AI AI AI AI AI AI AI AI AI AI AI

POT VOL CHANGE  
(-)0.056 IN.SIZE

18.0 17.0 13.4 1.0 4.4 0.23  
LIMITS PLASTIC SHRINKAGE PLASTICITY FLOW TOUGHNESS  
PCT LIMIT PCT INDEX PCT INDEX

(-)0.75 IN.SIZE  
SPECIF  
GRAVITY

ANGLE/REPOSE 1 IN OROP DEGREES AT 1.3 PCT MOIST MATERIAL SIZE(-)2.0 IN. ANGLE/SLIDE STEEL PLATE DEGREES AT 1.3 PCT MOIST APPARENT COHESION PSF AT PCT MOIST BULK DENSITY PCF AT PCT MOIST SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 2.2 PCT MOIST

2.70 40 37 32 NA NA 44

M-1 CURRENT: 1 SEPT. 1972

## KEY

6A  
TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE 10FT X 10FT	GRADE CFM PRESS EXHST	GPM	AIR WATER PUMP	PRIMARY SECONDARY
SHAPE HORSESHOE	0.25PCT 1SK X 26IN	20-400	8IN 4IN 10IN	4160V 440V
MODIFIED				
HAULAGE SYSTEM	SUPPORT SYSTEM			
MUCK RAIL, 36IN GAGE	HOLT, TYPE SIZE	ROOF PLATE	SET, SIZE, SHAPE	SHOTCRETE
75LB RAIL, 4.8	1IN X 7FT		4IN WF SETS, 4FT,	500PSI 18 MRS
CY CARS, 15TON	GROUPED 17PCT		3FT, 2FT FOR 23PCT	3750PSI 28 DAYS
LOCOMOTIVE				16 PCT OF 7200 FT

## MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
MAKE	WT CENTER INTERIOR	HEAD, CENTER	HEAD CENTER	CENTER
MODEL		KFTLB	KFTLB	KLB
		KFTLB	KFTLB	KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
				KLB

## CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES 3B	EXPLOSIVES, POWDER FACTOR 5.5LB/CY	BLASTING ELECTRICAL	MUCKING	GUIDANCE
JUMBO 4 BOOM HYDROJIB	DEPTH 10.5FT	TOTAL LBS 200	0-10 REGULAR DELAYS	EIMCO NO25 RAIL, ATR OPERATED	LASER
MACHINES 4-CF99	DIAM. 1-3/4IN	PRIMERS, GELEX 2-1 1/2 IN			
1-CF133	CUT. SPIRAL BURN	TRIM 20LB SHOOTTEX 70PCT X 7/8IN			
FEED LENGTH 12FT	SIN CENTER HOLE	INTERIOR GELEX 2-1 1/2 IN			
	SF/HOLE 2.6	CUT GELEX 2-1 1/2 IN			
		LIFTERS GELEX 2-1 1/2 IN			





KEY

7A  
TUNNEL DATA

TUNNEL		VENTILATION			WATER INFLOW		UTILITY LINES		POWER SYSTEM			
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	AIR	WATER	PUMP	PRIMARY	SECONDARY
10FT	MORSESHOE	+0.25% /	8K		X	26IN	150	8IN	4IN	10IN	4160V	480V
10FT	MODIFIED											
HAULAGE SYSTEM				SUPPORT SYSTEM				SET, SIZE, SHAPE				
				PERSONNEL				SHOTCRETE				
MUCK				RAIL								
RAIL, 35IN GAGE				SUPPLY								
75LB RAIL, 4.8				RAIL								
CY CARS, 15TON												
LOCOMOTIVE												

MACHINE EXCAVATION

MACHINE				CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES				TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	RPM	HEAD, CENTER	HEAD	CENTER	KFTLB	KFTLB
							KFTLB	KFTLB		KLB	KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE		EXPLOSIVES,		BLASTING		MUCKING		GUIDOANCE	
JUNBO	4 BOOM HYDROJIB	NO. HOLES	36-40	POWDER FACTOR	5.6LB/CY	ELECTRICAL	EINCO NO25	RAIL, AIR	
MACHINES	4-CF99	DEPTH	11FT	TOTAL LBS	225	0-10	REGULAR	OPERATED	
	1-CF133	DIAM.	1-3/4IN	PRIMERS,	GELEX 2	DELAYS			
		CUT,	SPIRAL BURN	TRIM	25LB 30PCT	OUPONT	7/8IN X 24IN		
			SIN CENTER HOLE	INTERIOR	GELEX 2				
			SF/HOLE	2.6	CUT GELEX 2				
					LIFTERS	GELEX 2			

KEY IDENTIFICATION  
8 LK  
SAMPLE NO  
LK-1

ROCK PROPERTIES  
IGNEOUS, BIOTITIC QUARTZ  
MONZONITE. FINE TO MEDIUM  
GRAINED PORPHYRY.

DRY WT PCF 162  
COMPR STRNTH KPSI 25  
RQD PCT EST 83  
SHORE MOH SCHMIDT NA  
HARDNESS NA

MUCK DATA  
DRY UNIT WT PCF 102  
MOISTURE PCT 0.4  
IN-SIZE PCT 66.8  
PER CENT BY WEIGHT BETWEEN SCREENS.  
6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200  
PCT (-) NO200 0.4

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

AI AI AI AI AI AI AI AI AI AI AI AI AI AI AI

POT VOL CHANGE (-)10.056 IN-SIZE  
LIQUID LIMIT PCT 18.10  
PLASTIC LIMIT PCT 17.98  
SHRINKAGE LIMIT PCT 17.69  
ATTERBERG LIMITS.  
SIZE (-) 0.056IN.  
PLASTICITY INDEX PCT 0.12  
FLOW INDEX PCT 3.90  
TOUGHNESS INDEX PCT 0.30

(-)10.75 IN-SIZE SPECIF GRAVITY 2.85  
ANGLE/REPOSE 1 IN DROP 0.8 PCT MOIST 23  
ANGLE/REPOSE 10 IN DROP 0.8 PCT MOIST 30  
ANGLE/SLIDE STEEL PLATE DEGREES AT 0.8 PCT MOIST 29  
ANGLE/SLIDE STEEL PLATE DEGREES AT 0.9 PCT MOIST 43S  
APPARENT ADHESION PSF AT 0.4 PCT MOIST 97.3  
BULK DENSITY PCF AT 0.0 PCT MOIST 43  
SIZE (-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 0.4 PCT MOIST

LK-1 CURRENT: 1 SEPT. 1972

## KEY

8A  
TUNNEL DATA

TUNNEL	VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS EXHST	SIZE	HP	AIR	WATER PUMP
18FT X	ARCHED	+5.5PCT	76K	HEAD SURF	48IN	150	6IN	2IN
16FT	BACK							
HAULAGE SYSTEM	PERSONNEL		SUPPLY		SUPPORT SYSTEM		SET, SIZE, SHAPE	
MUCK	WAGNER ST-8	DIESEL	DIESEL		BOLT, TYPE SIZE		SHOTCRETE	
SCOOPTRAM,	TRUCK	TRUCK	TRUCK		13.5IN X 9FT,			
RAIL SKIP					AT 4FT			

## MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES		RPM	TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD, CENTER	HEAD
						KFTLB	KFTLB
						KFTLB	KFTLB
							KLB
							KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDOANCE	THRUST/SQ FT
--------------	-------------	--------------	-----------	--------------

KLB

## CONVENTIONAL EXCAVATION

MACHINE	ROUND,		EXPLOSIVES,		BLASTING		GUIDANCE	
JUNRC	3	BOOM	POWDER FACTOR		ELECTRICAL		LASER	
MACHINES	GARROWER	OENVER	4.0 LB/CY		0-15 REGULAR		SCOOPTRAM	
	1-PR123	DEPTH 16.5FT	TOTAL LBS 365		DELAYS			
	2-DW123	DIAM. 1-3/4IN	PRIMERS, 25LB 1.5IN X 8IN, 60-75PCT					
	DRIFTER	CUT, 6 HOLE BURN	TWIN 25LB 7/8IN X 16IN, 30PCT					
FEED LENGTH	12FT	1-4IN CNTR HOLE	INTERIOR ANFO					
		SF/HOLE 5.4	CUT 40LB 1.5IN X 16IN, 45PCT					
			LIFTERS ANFO					

LK-1

CURRENT: 09/01/72

KEY IDENTIFICATION  
9 LK

SAMPLE NO  
LK-2

ROCK PROPERTIES  
IGNEOUS: BIOTITIC QUARTZ  
MONZONITE, FINE TO MEDIUM  
GRAINED PORPHYRY, WITH MINOR  
STEELY INCLINED JOINS.

DRY  
WT  
PCF

COMPR  
STRNTH  
KPSI

RQD  
PCT  
EST

SHORE  
MOH

HARDNESS  
SCHMIDT

16S

28

83

4A

NA

NA

MUCK DATA  
DRY UNIT  
WT PCF

MOISTURE  
PCT

PCT(1-16  
IN SIZE

PER CENT BY WEIGHT BETWEEN SCREENS

6IN. 3IN. 2IN. 1IN. 1/2IN. NO4

NO8 NO16 NO30 NO50 NO100 NO200

PCT (-)  
NO200

103

1.6

49.1

16.9

8.7

5.8

5.3

2.0

1.8

1.3

1.0

0.8

0.5

1.3

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

AI

AI

AI

AI

AI

AI

AI

AI

AI

POT VOL CHANGE  
(-)0.05% IN SIZE

LIQUID  
LIMITS  
PCT

PLASTIC  
LIMIT  
PCT

ATTERRERG LIMITS..SIZE(-) 0.056IN.

SHRINKAGE  
LIMIT  
PCT

PLASTICITY  
INDEX

FLOW  
INDEX

TOUGHNESS  
INDEX

0

20.50

19.14

17.29

0.36

6.2

0.058

(-)0.75 IN SIZE  
SPECIF  
GRAVITY

ANGLE/REPOSE  
1 IN DROP

DEGREES AT  
4.7 PCT MOIST

MATERIAL SIZE(-)2.0

ANGLE/REPOSE  
10-IN DROP

DEGREES AT  
4.7 PCT MOIST

APPARENT  
COHESION  
PSF AT

BULK  
DENSITY  
PCF AT

PCT MOIST 0.0 PCT MOIST

SIZE(-)2.0

ANGLE INTER  
FRICTION

DEGREES AT  
4.9 PCT MOIST

2.73

42

33

210

97.6

39

LK-2

CURRENT: 1 SEPT. 1972

## KEY

9A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS EXHST	SIZE	HP	AIR WATER PUMP	PRIMARY	SECONDARY
18FT X 16FT	ARCHED BACK	+2.0PCT	22K	HEAD	SUNF	48IN	6IN 2IN	4160V	220V
HAULAGE SYSTEM		SUPPORT SYSTEM		SET SIZE SHAPE		SHOTCRETE			
MUCK	WAGNER ST-8	PERSONNEL	SUPPLY	DIESEL	TRUCK	TRUCK	ROOF PLATE		
SCOOPTRAIL	RAIL SKIP	DIESEL TRUCK	3/4IN X 6FT	AT 4FT	13.5IN X 9FT				
MACHINE EXCAVATION		CUTTERS MAKE TYPE DIAM CUTTING EDGES		RPM		TORQUE MAX/OPERATE		THRUST MAX/OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD CENTER	HEAD	CENTER	
						KFTLB	KFTLB	KFTLB	KLB
						KFTLB	KFTLB	KFTLB	KLB
ANCHOR PRESS		MUCK SYSTEM		POWER SYSTEM		GUIDANCE		THRUST/50 FT	
									KLB
CONVENTIONAL EXCAVATION		EXPLOSIVES		POWDER FACTOR		4LB/CY		BLASTING	
MACHINE	JUMBO 3 500N	ROUND	NO. HOLES	47	DEPTH	10.5FT		ELECTRICAL	GUIDANCE
MACHINES	GAPORNEW	OENVER	3-PR123	ORIFTER	OIAM	1-3/4IN		0-15 REGULAR	LASER
		CUT	6 HOLE BURN		TRIM	25LB 7/8IN X 16IN, 30PCT		DELAYS	
FEED LENGTH	12FT		1-4IN CNTR HOLE		INTERIOR ANFO				
			SF/HOLE 5.4		CUT 40LB 1.5IN X 16IN, 45PCT				
					LIFTERS ANFO				

LK-2

CURRENT: 09/02/72

KEY IDENTIFICATION

IO LK  
SAMPLE NO  
LK-S

ROCK PROPERTIES

IGNEOUS: BIOTITIC QUARTZ  
MONZONITE, FINE TO MEDIUM  
GRAINED PORPHYRY

DRY WT PCF 16S  
COMPR STRNTH KPSI 32  
R00 PCT EST 92  
SHORE MOH NA  
HARDNESS SCHMIDT NA

MUCK DATA

DRY UNIT WT PCF 94 16.8  
MOISTURE PCT IN SIZE 0.0 0.0 0.0 0.0 13.0 14.0 20.0 7.0 8.0 8.0 8.0 6.0 5.0 11.0  
PCT (-) 16 IN SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 NO700

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PE PI PI A A A A A A

POT VOL CHANGE (-)0.056 IN SIZE

LIQUID LIMIT PCT 25.00  
PLASTIC LIMIT PCT 20.95  
SHrinkage LIMIT PCT 19.68  
ATTENRG LIMITS SIZE (-) 0.056IN.  
PLASTICITY INDEX 4.05  
FLOW INDEX 5.50  
TOUGHNESS INDEX 0.73

(-)0.056IN SIZE SPECIF GRAVITY

ANGLE/REPOSE 1 IN DROP 3.4 PCT MOIST  
ANGLE/REPOSE 10 IN DROP 3.4 PCT MOIST  
ANGLE/REPOSE 30 IN DROP 3.4 PCT MOIST  
MATERIAL SIZE (-)2.0 IN.  
ANGLE/SLIDE STEEL PLATE DEGREES AT 3.4 PCT MOIST  
APPARENT COMESION PSF AT 3.0 PCT MOIST  
BULK DENSITY PCF AT 0.0 PCT MOIST  
SIZE (-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 3.0 PCT MOIST

2.67

33

32

38

75

100

37

LK-S

CURRENT: 1 SEPT. 1972

KEY

10A

# TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE 12FT	CFM NONE	GPM NONE	AIR WATER PUMP NA	PRIMARY SECONDARY 440V
13-7/8IN PILOTHOLE	PRESS EXHST NONE	HP		
MAULAGE SYSTEM	SUPPORT SYSTEM			
	ROLL-TYPE SIZE ROOF PLATE		SET-SIZE, SHAPE NONE	SHOTCRETE
	SUPPLY DIESEL TRUCK			
	PERSONNEL DIESEL TRUCK			
MUCK WAGNER ST-8 SCOOPTRAM RAIL SKIP				

## MACHINE EXCAVATION

MACHINE	CUTTERS-MAKE-TYPE-DIAM-CUTTING EDGES	RPM	TORQUE-MAX/OPERATE	THRUST-MAX/OPERATE
MAKE ROBBINS	CENTER INTERIOR 19 ROBBINS 12IN 3 ROBBINS, 12IN STEEL DISC, 2-II IN TWIN STEEL DISC	HEAD-CENTER HEAD 6	CENTER	
MODEL M81R RAISE DRILL	WT 49 TONS	WFTLB 583 WFTLB 266	WFTLB WFTLB	KL8 814 KL8 490-510

ANCHOR PRESS	MUCK SYSTEM GRAVITY	POWER SYSTEM ELECTRIC MOTORS 3-100 HP	GUIDANCE SURVEY IN PILOT HOLES	THRUST/50 FT KL8 4.46
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## CONVENTIONAL EXCAVATION

MACHINE JUNHO MACHINES	ROUND- NO. HOLES DEPTH DIAM. CUT.	EXPLOSIVES, POWDER FACTOR TOTAL LBS PRIMERS, TRIM INTERIOR CUT LIFTERS	BLASTING	MUCKING	GUIDANCE
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FEED LENGTH

LK-S

CURRENT: 09/01/72

COMPR  
STRNTH  
ROD  
PCT  
.....HARNESS.....  
SHORE MOH SCHMIOT

SAMPLE NO  
LK-6

MUCK DATA  
 DAY UNIT  
 WT. PCF

[illegible][illegible]

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES    A=ANGULAR   S=SUBANGULAR   R=ROUNDED   P=PLATY   C=CUBIC   I=IRREGULAR   E=ELONGATED   SP=SPHEROID

AI

POT VOL CHANGE  
(-)0.056 IN.SIZE

[illegible]

9

	1.24	4.00	0.31
1967-68	1.24	4.00	0.31
1968-69	1.24	4.00	0.31
1969-70	1.24	4.00	0.31
1970-71	1.24	4.00	0.31
1971-72	1.24	4.00	0.31
1972-73	1.24	4.00	0.31
1973-74	1.24	4.00	0.31
1974-75	1.24	4.00	0.31
1975-76	1.24	4.00	0.31
1976-77	1.24	4.00	0.31
1977-78	1.24	4.00	0.31
1978-79	1.24	4.00	0.31
1979-80	1.24	4.00	0.31
1980-81	1.24	4.00	0.31
1981-82	1.24	4.00	0.31
1982-83	1.24	4.00	0.31
1983-84	1.24	4.00	0.31
1984-85	1.24	4.00	0.31
1985-86	1.24	4.00	0.31
1986-87	1.24	4.00	0.31
1987-88	1.24	4.00	0.31
1988-89	1.24	4.00	0.31
1989-90	1.24	4.00	0.31
1990-91	1.24	4.00	0.31
1991-92	1.24	4.00	0.31
1992-93	1.24	4.00	0.31
1993-94	1.24	4.00	0.31
1994-95	1.24	4.00	0.31
1995-96	1.24	4.00	0.31
1996-97	1.24	4.00	0.31
1997-98	1.24	4.00	0.31
1998-99	1.24	4.00	0.31
1999-00	1.24	4.00	0.31
2000-01	1.24	4.00	0.31
2001-02	1.24	4.00	0.31
2002-03	1.24	4.00	0.31
2003-04	1.24	4.00	0.31
2004-05	1.24	4.00	0.31
2005-06	1.24	4.00	0.31
2006-07	1.24	4.00	0.31
2007-08	1.24	4.00	0.31
2008-09	1.24	4.00	0.31
2009-10	1.24	4.00	0.31
2010-11	1.24	4.00	0.31
2011-12	1.24	4.00	0.31
2012-13	1.24	4.00	0.31
2013-14	1.24	4.00	0.31
2014-15	1.24	4.00	0.31
2015-16	1.24	4.00	0.31
2016-17	1.24	4.00	0.31
2017-18	1.24	4.00	0.31
2018-19	1.24	4.00	0.31
2019-20	1.24	4.00	0.31
2020-21	1.24	4.00	0.31
2021-22	1.24	4.00	0.31
2022-23	1.24	4.00	0.31
2023-24	1.24	4.00	0.31
2024-25	1.24	4.00	0.31
2025-26	1.24	4.00	0.31
2026-27	1.24	4.00	0.31
2027-28	1.24	4.00	0.31
2028-29	1.24	4.00	0.31
2029-30	1.24	4.00	0.31
2030-31	1.24	4.00	0.31
2031-32	1.24	4.00	0.31
2032-33	1.24	4.00	0.31
2033-34	1.24	4.00	0.31
2034-35	1.24	4.00	0.31
2035-36	1.24	4.00	0.31
2036-37	1.24	4.00	0.31
2037-38	1.24	4.00	0.31
2038-39	1.24	4.00	0.31
2039-40	1.24	4.00	0.31
2040-41	1.24	4.00	0.31
2041-42	1.24	4.00	0.31
2042-43	1.24	4.00	0.31
2043-44	1.24	4.00	0.31
2044-45	1.24	4.00	0.31
2045-46	1.24	4.00	0.31
2046-47	1.24	4.00	0.31
2047-48	1.24	4.00	0.31
2048-49	1.24	4.00	0.31
2049-50	1.24	4.00	0.31
2050-51	1.24	4.00	0.31
2051-52	1.24	4.00	0.31
2052-53	1.24	4.00	0.31
2053-54	1.24	4.00	0.31
2054-55	1.24	4.00	0.31
2055-56	1.24	4.00	0.31
2056-57	1.24	4.00	0.3

**0.75IN.SIZE**

*****MATERIAL SIZE(-) 2.0 IN*****		*****		SIZE(-) 2.0 IN.	
ANGLE/REPOSE	ANGLE/SLOPE	APPARENT	BULK	ANGLE INTER	
1 IN DROP	STEEL PLATE	COMESION	DENSITY	FRICTION	
DEGREES AT	DEGREES AT	PSF AT	PCF / I	DEGREES AT	
3.7 PCT MOIST	3.7 PCT MOIST	0.2 PCT MOIST	0.0 PCT MOIST	0.2 PCT MOIST	

2.53

	29	32	0	1.1	40
1					
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99					
100					

LK-6

**CURRENT: 1 SEPT. 1972**



11A  
TUNNEL DATA

SIZE	SHAPE
4FT	ROUND
13 7/8IN	PILOTHOLE

CFM	PRESS	EXHST	SIZE	HP
		NONE		

AIR WATER PUMP  
NA

PRIMARY SECONDARY 440V

TRUCK  
WAGNER ST-8  
SCOOPTRAM

## SUPPORT SYSTEM

**SET, SIZE, SHAPE**

## SHOTCRETE

**B-22**

MOORE  
HARRIS  
ORILL

**CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES**

INTERIOR GAGE  
4 ROBBINS 12IN . 1 ROBBINS 12IN  
TWIN STEEL TWIN STEEL  
DISCS DISCS

**TORQUE • MAX/OPERATE**

**THRUST • MAX/OPERATE**

## GRAVITY

**MOTORS**  
**3-100 HP**

GUIDANCE THRUST/SQ FT

IN PILOT KLH 17.2  
HOLE

**MACHINE  
JUMBO  
MACHINES**

ROUND,  
NO. HOLES  
DEPTH  
DIAM.  
CUT.

EXPLOSIVES,  
POWDER FACTOR  
TOTAL LBS  
PRIMERS,  
TRIM  
INTERIOR  
CUT  
LIFTERS

## BLASTING

## HUCKING

## GUIDANCE

## FEED LENGTH

KEY IDENTIFICATION  
12 LK

SAMPLE NO  
LK-7

ROCK PROPERTIES

IGNEOUS: QUARTZ MONZONITE  
PORPHYRY, INTENSELY ALTERED  
COARSE GRAINED

DRY

WT  
PCF

158

COMPR

STRNTH  
KPSI

7

ROD

PCT  
EST

35

SHORE

MOH SCHMIDT

NA

WUCK DATA

DRY UNIT

WT PCF

MOISTURE

PCT IN-SIZE

PCT IN-SIZE

61.3 3IN. 2IN. 1IN. 1/2IN. NO4

PER CENT BY WEIGHT BETWEEN SCREENS

NO8 NO16 NO30 NO50 NO100 NO200

PCT (-)

MD200

107 9.7 13.1

14.0 11.2 12.3 15.5

14.2 4.3

3.7 3.1

1.9 1.2

1.2 4.3

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

A

A

A

A

A

A

A

A

A

A

A

A

A

POT VOL CHANGE  
(-10.056 IN-SIZE

LIQUID LIMITS  
PCT

18.00

17.12

17.04

0.88

5.00

0.18

0.18

0.18

0.18

0.18

0.18

0.18

(-10.75 IN-SIZE  
SPECIFIC GRAVITY

ANGLE/REPOSE  
1 IN DROPS

10.7 IN DROPS

1.7 PCT MOIST

1.7 PCT MOIST

1.7 PCT MOIST

1.7 PCT MOIST

1.7 PCT MOIST

1.7 PCT MOIST

1.7 PCT MOIST

1.7 PCT MOIST

1.7 PCT MOIST

1.7 PCT MOIST

1.7 PCT MOIST

2.6R

29

25

28

70

114

45

45

45

45

45

45

45

45

LK-7

CURRENT: 1 SEPT. 1972

KEY

12A  
TUNNEL DATA

TUNNEL  
SIZE 15FT X 14 FT BACK  
SHAPE ARCHED  
GRADE -26PCT  
VENTILATION CFM 22K X  
PRESS EXHST 22K X  
SIZE 48IN  
MP 150  
WATER INFLOW GPM MINOR  
AIR WATER PUMP 6IN 2IN 4IN  
UTILITY LINES  
POWER SYSTEM PRIMARY SECONDARY 4160 220

HAULAGE SYSTEM

MUCK WAGNER ST-8  
SCOOP TRAM  
RAIL SKIP  
PERSONNEL DIESEL TRUCK  
SUPPLY DIESEL TRUCK  
SUPPORT SYSTEM  
BOLI, TYPE SIZE MOOF PLATE 6FTX3/4INX4FT 13.5INX9FT  
SET, SIZE, SHAPE SHOT, C, E, T, E

MACHINE EXCAVATION

MACHINE  
MAKE MODEL WT CENTER INTERIOR GAGE RPM HEAD, CENTER HEAD TORQUE, MAX/OPERATE THRUST, MAX/OPERATE  
KFTLB KFTLB KFTLB KFTLB KFTLB KFTLB KFTLB KFTLB KFTLB KFTLB

ANCHOR PRESS MUCK SYSTEM POWER SYSTEM GUIDANCE THRUST/SQ FT  
KLB KLB

CONVENTIONAL EXCAVATION

MACHINE JUMBO 3 BOOM  
MACHINES PR-123  
FEED LENGTH 12FT  
ROUND, NO. HOLES 42  
DEPTH 18-5  
DIAM. 1.75  
CUT, TURN 4 IN CENTER  
EXPLOSIVES, POWDER FACTOR 4.7 LB/CY  
TOTAL LBS 350  
PRIMERS, 25LB, 1.5X8IN, 60PCT  
TRIM 25LB, 7/8X16IN, 30PCT  
INTERIOR CUT  
LIFTERS  
BLASTING ELECTRICAL 0-15 INFEEDER DELAY  
MUCKING SCOOP TRAM  
GUIDANCE LASER

LK-7 CURRENT: 09/01/72



KEY

13A  
TUNNEL DATA

TUNNEL

SIZE 12FT X 12FT  
SHAPE RECT

VENTILATION

GRADE +0.4PCT  
CFM 14K X  
PRESS EXHST 24IN 60

WATER INFLOW

GPM NONE

UTILITY LINES

AIR WATER PUMP  
4IN 2IN 8IN

POWER SYSTEM

PRIMARY 2400  
SECONDARY 480

HAULAGE SYSTEM

MUCK RAIL 10 TON  
GAIL 10 TON  
BOTTOM DUMP  
36 IN GAGE  
45 LB

SUPPORT SYSTEM

BOLT TYPE SIZE ROOF PLATE

SUPPLY RAIL

SHOTCRETE

SET SIZE SHAPE  
12IN H BEAM  
10FT X 12IN X 12IN  
POSTS 2 5FT

MACHINE EXCAVATION

MACHINE

CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES

THRUST, MAX/OPERATE

MAKE MODEL

WT

CENTER

INTERIOR

GAGE

RPM

TORQUE, MAX/OPERATE

CENTER

KL8  
KL8

ANCHOR PRESS MUCK SYSTEM POWER SYSTEM GUIDANCE THRUST/SQ FT

KL8

KL8

CONVENTIONAL EXCAVATION

MACHINE JUMBO 2 ROOM  
MACHINES CF79  
OR 0 89

FEED LENGTH 6 FT

ROUNDING  
NO. HOLES 52  
DEPTH 5 FT  
DIAM. 1 5/8 IN  
CUT. WEDGE

EXPLOSIVE  
POWDER FACTOR 3.5 LB/CT  
TOTAL LB 100  
PRIMERS, PRIMACOR  
TRIM ANODEL  
INTERIOR ANODEL  
CUT ANODEL  
LIFTERS ANODEL

BLASTING  
IGNITER CORD  
FUSE, NO 6  
C-95

MUCKING  
EIMCO 40  
LOADER

GUIDANCE  
TRANSIT

KEY IDENTIFICATION  
14 CLIMAX  
SAMPLE NO  
CL-1

ROCK PROPERTIES  
METAMORPHIC: GRANITIC GNEISS,  
HIGHLY METAMORPHOSED,  
MODERATELY TO HIGHLY  
FRACTURED, HIGHLY SILICIFIED.

DRY WT PCF 174  
COMPR STRNTH KPSI 9  
ROD PCT EST 10  
SHORE MOH SCHMIDT NA

MUCK DATA

DRY UNIT WT PCF 87  
MOISTURE PCT 8.9  
PCT IN-SIZE 0.0  
PER CENT BY WEIGHT BETWEEN SCREENS.....  
6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 PCT (-) NO200

87 8.9 0.0 0.0 0.0 0.0 4.8 37.8 18.1 11.2 8.5 6.8 5.6 5.4 1.8

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

AI AI AI AI AI AI AI AI

POT VOL CHANGE (-) IN-SIZE

LIQUID LIMIT PCT NA  
PLASTIC LIMIT PCT NA  
SHRINKAGE LIMIT PCT NA  
ATTERBERG LIMITS..SIZE(-) IN.....  
PLASTICITY INDEX PCT NA  
FLOW INDEX NA  
TOUGHNESS INDEX NA

(-) IN-SIZE \*.....  
ANGLE/REPOSE 10 IN DROP DEGREES AT PCT MOIST  
ANGLE/REPOSE 10 IN DROP DEGREES AT PCT MOIST

MATERIAL SIZE (-) IN.....  
ANGLE/SLIOE STEEL PLATE DEGREES AT PCT MOIST  
ANGLE/SLIOE STEEL PLATE DEGREES AT PCT MOIST

APPARENT COHESION PSF AT PCT MOIST  
BULK DENSITY PCF AT PCT MOIST

SIZE(-) IN. ANGLE INTER FRICTION DEGREES AT PCT MOIST

NA NA NA NA NA NA NA NA

CL-1

CURRENT: 1 SEPT. 1972

## KEY

14A  
TUNNEL DATA

TUNNEL	VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE 13FT	GRADE 0.025PCT 10K	CFM	PRESS EXHST X	SIZE 24IN	HP	GPM	AIR WATER PUMP	PRIMARY SECONDARY
						5-10	4IN 2IN	415V 480V

HAULAGE SYSTEM	SUPPORT SYSTEM		SET, SIZE, SHAPE		SHOTCRETE	
MUCK RAIL	PERSONNEL RAIL	SUPPLY RAIL	BOLT, TYPE SIZE	ROOF PLATE		
			NONE			

## MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES		RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
MAKE CALVELLO	MODEL 40	WT 200 TONS	INTERIOR 12 SMITH ICB 6 SMITH ICB 6 SMITH ICB	HEAO CENTER	KLB 133 KLB 130
			TRICONE, 24IN	KFTLB 347 KFTLB	

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDOANCE	THRUST/50 FT
KLB	BUCKET FROM FACE, CONVEYOR TO WEAR 24IN	ELECTRO-HYDRAULIC 825 HP	LASER	KLB 5.09

## CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES	ROUND, NO. HOLES DEPTH DIAM. CUT.	EXPLOSIVES, POWDER FACTOR TOTAL LBS PRIMERS, TRIM INTERIOR CUT LIFTERS	BLASTING	MUCKING	GUIDOANCE
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## FEED LENGTH

CL-1 CURRENT: 09/01/72

KEY IDENTIFICATION  
IS LK  
SAMPLE NO  
LK-3

ROCK PROPERTIES  
METAMORPHIC: INTERLAYERED  
TRANSITION BETWEEN QUARTZITE  
AND TACTITE, MODERATELY TO  
STRONGLY ALIGNED METASEDIMENTS  
WITH REPLACEMENT PYRITE.  
CHALCOPYRITE AND MAGNETITE AND  
A HIGH PERCENTAGE OF SILICATES  
VERY FINE TO MEDIUM  
GRAINED.

ORY  
WT  
PCF  
178  
26  
80  
NA  
NA  
NA  
SHORE MOH SCHMIOT

MUCK DATA  
DRY UNIT  
WT PCF  
105 0.1 34.1 17.4 9.1 10.2 10.6 8.7 2.8 1.6 1.2 0.8 0.8 0.4 2.3  
MOISTURE PCT(+)16  
PCT 1A-SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 PCT (-) NO200

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND P=PLATE C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

AI AI AI AI AI AI AI AI AI AI AI AI AI AI AI

POT VOL CHANGE  
(-)0.054 IN-SIZE  
0 18.25 17.92 17.80 0.33 5.50 0.06  
\*.....ATTERBERG LIMITS...SIZE(-) 0.056IN.....  
LIQUID PLASTIC SHINKAGE PLASTICITY FLOW TOUGHNESS  
LIMIT LIMIT INOEK INOEK INDEX INDEX

(-)10.75 IN-SIZE \*.....MATERIAL SIZE(-)12.0 IN.....  
SPECIF ANGLE/REPOSE 1 IN DROP 10 IN DROP STEEL FLATE APPARENT BULK SIZE(-)12.0 IN.  
GRAVITY DEGREES AT DEGREES AT DEGREES AT PSF AT DENSITY ANGLE INIER  
1.5 PCT MOIST 1.5 PCT MOIST 1.5 PCT MOIST 0.4 PCT MOIST 0.0 PCT MOIST 0.4 PCT MOIST FRICTION  
3.21 30 29 29 175 117.8 41

LK-3 CURRENT: 1 SEPT. 1972







16A  
TUNNEL DATA

SIZE 15FT X 14FT.  
SHAPE ARCHED BACK

GRADE	CFM	PRESS	EXHST	SIZE
+2.0PCT	50K	HEAD	SURF	48IN

4P	GPM
150	NONE

AIR WATER PUMP  
6IN 2IN

PRIMARY 4160V  
SECONDARY 220V

MUCK  
 WAGNER ST-8  
 SCOOPTRAM  
 RAIL, SHIP

NONE

SET SIZE & SHAPE  
60 IN WIDE STEEL SETS  
AT 50%

## SHOTCRETE

**MACHINE CUTTERS, MAKE TYPE, VARIOUS CUTTING EDGES**

**THRUST, MAX/OPERATE**

HEAD CENTER

KL 8  
KL 8

87X

MACHINE JUMBO 3 ROOM NG. HOLES 42  
MACHINES GARDNER DENVER DEPTH 6 FT  
3-PR123 OIAM. 1-3/4 IN  
DRIFTERS 6 HOLE BURN  
FEED LENGTH 12 FT CUT. 1-4 IN CENTER  
HOLE  
SF/HOLE 4.4

EXPLOSIVES,  
POWDER FACTOR 5.5LB/CY  
TOTAL LBS 205  
PRIMERS, 15LB 1-SIN X 8IN, 60-75PCT  
TRIM 15LB 7/8IN X 16IN, 30PCT  
INTERIOR ANFO  
CUT 25LB 1-SIN X 16IN, 45PCT  
LIFTERS ANFO

**BLASTING  
ELECTRICAL  
0-15 REGULAR  
DELAYS**

**MUCKING  
SCOOPTRAM**

4-X77

CURRENT: 09/01/72

KEY IDENTIFICATION  
17 MATHER B  
SAMPLE NO  
48-1

ROCK PROPERTIES  
METAMORPHIC: INTER LAYERED  
BANDS HEMATITE AND MANKITE  
HIGHLY JOINTED NORMALLY FLAT  
LYING, OFTEN HIGHLY FULDEO.  
NATURAL IRON OVER 60 PCT  
MOISTURE 9 PCT, SILICA 5 PCT.

DRY  
WT  
PCF  
207

COMPR  
STRNTH  
KPSI  
7

ROO  
PCT  
EST  
10

SHORE  
MOH  
NA

HARDNESS  
MOH  
NA

SCHMIDT  
NA

MUCK DATA  
DRY UNIT  
WT PCF  
128 7.2 7.2 9.7 1.4 8.7 11.4 20.1 10.3 7.4 3.3 1.8 1.3 1.1 16.3

MOISTURE  
PCT  
P-T(+)16  
IN-SIZE  
6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200

PER CENT BY WEIGHT BETWEEN SCREENS.....\* PCT (-)  
NO200

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

AI AI AI AI AI AI AI AI AI AI AI AI AI AI AI

POT VOL CHANGE  
(-)0.056 IN-SIZE  
0 17.8 15.1 13.9 2.7 4.1 0.66

LIQUID  
LIMITS  
PCT

PLASTIC  
LIMIT  
PCT

SHRINKAGE  
LIMIT  
PCT

PLASTICITY  
INDEX  
PCT

FLOW  
INDEX

TOUGHNESS  
INDEX

(-)0.75 IN-SIZE  
SPECIF  
GRAVITY  
4.34 37 35 31 235 141 35

ANGLE/REPOSE  
1 IN DROP  
DEGREES AT  
6.2 PCT MOIST

ANGLE/SLIDE  
STEEL PLATE  
DEGREES AT  
6.2 PCT MOIST

APPARENT  
PSF AT  
6.9 PCT MOIST

BULK  
DENSITY  
PCF AT  
0.0 PCT MOIST

SIZE(-)2.0  
IN.  
ANGLE INTER  
FRICTION  
DEGREES AT  
6.9 PCT MOIST

48-1 CURRENT: 1 SEPT. 1972

## KEY

17A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR	WATER PUMP
9FT	ROUND	3K	X		8IN	5	NONE	2IN	11IN
11.5IN									
HAULAGE SYSTEM		PERSONNEL		SUPPORT SYSTEM		SET, SIZE, SHAPE		SHOTCRETE	
MUCK	42IN SCRAPER	RAIL	SUPPLY	BOLT, TYPE	SIZE	ROOF PLATE	9FT 6IN DIA. X		
RAIL	MOIST	RAIL	MOIST				4IN WF AT 45IN		

## MACHINE EXCAVATION

MACHINE		CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES		RPM		TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD, CENTER	HEAD	CENTER	
CALWELD	OCCILLATOR	69 TONS	258 CARBOLOY DRAG BITS	20 CARBOLOY RIPPERS		8	KFTLB 1200 KFTLB	KFTLB	KLB 300 KLB 285

ANCHOR PRESS	MUCK SYSTEM	GUIDANCE	THRUST/SQ FT
KLB 285	FLIGHT CONVEYOR TO REAR OF MACHINE	RE-OTE HYDRAUL. PUMPS, 2-90GPM, 2500 PSI, 2-125 HP MOTORS	KLB 3.66

## CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES	EXPLOSIVES, POWDER FACTOR	GUIDANCE
JUMBO MACHINES	DEPTH DIAM. CUT.	TOTAL LBS PRIMERS, TRIM INTERIOR CUT	MUCKING
FEED LENGTH		LIFTERS	

.....HARNESS.....  
SHORE MOH SCHMIOT

22

BEFORE SCREENS..... PCT (-)

B-35

PLASTICITY INDEX FLOW INDEX TOUGHNESS INDEX

APPARENT	BULK
COHESION	DENSITY
PSF AT	PCF AT
	PCF MOIST

SIZE (-)	IN.	ANGLE INTER FRICTION DEGREES AT
1/2	1.315	10
3/4	1.875	15
1	2.375	20
1 1/4	3.125	25
1 1/2	3.750	30
2	5.000	40
2 1/2	6.250	50
3	7.500	60
3 1/2	8.750	70
4	10.000	80
4 1/2	11.250	90
5	12.500	100
5 1/2	13.750	110
6	15.000	120
6 1/2	16.250	130
7	17.500	140
7 1/2	18.750	150
8	20.000	160
8 1/2	21.250	170
9	22.500	180
9 1/2	23.750	190
10	25.000	200
10 1/2	26.250	210
11	27.500	220
11 1/2	28.750	230
12	30.000	240
12 1/2	31.250	250
13	32.500	260
13 1/2	33.750	270
14	35.000	280
14 1/2	36.250	290
15	37.500	300
15 1/2	38.750	310
16	40.000	320
16 1/2	41.250	330
17	42.500	340
17 1/2	43.750	350
18	45.000	360
18 1/2	46.250	370
19	47.500	380
19 1/2	48.750	390
20	50.000	400
20 1/2	51.250	410
21	52.500	420
21 1/2	53.750	430
22	55.000	440
22 1/2	56.250	450
23	57.500	460
23 1/2	58.750	470
24	60.000	480
24 1/2	61.250	490
25	62.500	500
25 1/2	63.750	510
26	65.000	520
26 1/2	66.250	530
27	67.500	540
27 1/2	68.750	550
28	70.000	560
28 1/2	71.250	570
29	72.500	580
29 1/2	73.750	590
30	75.000	600
30 1/2	76.250	610
31	77.500	620
31 1/2	78.750	630
32	80.000	640
32 1/2	81.250	650
33	82.500	660
33 1/2	83.750	670
34	85.000	680
34 1/2	86.250	690
35	87.500	700
35 1/2	88.750	710
36	90.000	720
36 1/2	91.250	730
37	92.500	740
37 1/2	93.750	750
38	95.000	760
38 1/2	96.250	770
39	97.500	780
39 1/2	98.750	790
40	100.000	800
40 1/2	101.250	810
41	102.500	820
41 1/2	103.750	830
42	105.000	840
42 1/2	106.250	850
43	107.500	860
43 1/2	108.750	870
44	110.000	880
44 1/2	111.250	890
45	112.500	900
45 1/2	113.750	910
46	115.000	920
46 1/2	116.250	930
47	117.500	940
47 1/2	118.750	950
48	120.000	960
48 1/2	121.250	970
49	122.500	980
49 1/2	123.750	990
50	125.000	1000

CURRENT: 1 SEPT. 1972.

KEY

18A  
TUNNEL DATA

TUNNEL

SIZE  
10FT X  
9FT 6 IN

SHAPE  
RECT

GRADE  
0

VENTILATION  
CFM 4K X  
PRESS EXHST  
SIZE 15  
HP 15

WATER INFLOW  
GPM  
NONE

UTILITY LINES  
AIR WATER PUMP  
2IN 1IN

POWER SYSTEM  
PRIMARY 230V  
SECONDARY 440V

HAULAGE SYSTEM

PERSONNEL  
RAIL

SUPPLY  
RAIL

SUPPORT SYSTEM

BOLT, TYPE SIZE ROOF PLATE

SHOTCRETE

SET, SIZE, SHAPE  
8IN-S8LB WF SETS  
7FT CAP, 8FT POSTS  
WOOD LAGGING  
PIPE SPILING  
8-1IN DIA-6-2IN DIA

MACHINE EXCAVATION

MACHINE

MAKE  
ALPINE

MODEL  
F-6A

WT  
11T

CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES  
CENTER INTERIOR GAGE  
68 KENAMETAL 43KH TCB  
ON TWIN RIPPER HEADS

RPM

HEAD, CENTER HEAD CENTER  
60

TORQUE, MAX/OPERATE THRUST, MAX/OPERATE  
KFTLB49 HP KFTLB KFTLB  
KFTLB KFTLB KLB 2-10  
KLB

ANCHOR PRESS

MUCK SYSTEM  
GATHERING  
ARMS, FLIGHT  
CONVEYORS

POWER SYSTEM  
440V

GUIDANCE THRUST/SQ FT  
TRANSIT KLB

CONVENTIONAL EXCAVATION

MACHINE  
JUMBO  
MACHINES

ROUND,  
NO. HOLES  
DEPTH  
DIAM.  
CUT,

FEED LENGTH

EXPLOSIVES,  
POWDER FACTOR  
TOTAL LBS  
PRIMERS,  
TRIM  
INTERIOR  
CUT  
LIFTERS

BLASTING MUCKING GUIDANCE

MB-3

CURRENT: 09/01/72

KEY IDENTIFICATION

19 ST

SAMPLE NO  
ST-1

ROCK PROPERTIES

METAMORPHIC: ARGILLACEOUS  
QUARTZITE, MEDIUM TO THIN  
BEDDED, MODERATELY TO HIGHLY  
FOLDED, MODERATE FRACTURING

DRY  
WT  
PCF

COMPR  
STRENGTH  
KPSI

RQC  
PCT  
EST

SHORE  
60H

IRONNESS  
SCHMIDT

NA

NA

75

NA

MUCK DATA

DRY UNIT  
WT PCF

MOISTURE  
PCT

PCT(+)

IN-SIZE

6IN. 3IN. 2IN. 1IN. 1/2IN. NO4

PER CENT BY WEIGHT BETWEEN SCREENS

NO16 NO30 NO50 NO100 NO200

NO260

PCT (-)

NO260

NO100

NO50

NO30

NO16

NO8

NO4

NO2

NO1

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID

POT VOL CHANGE  
(-)

IN-SIZE

PLASTIC  
LIMIT  
PCT

SHRINKAGE  
LIMIT  
PCT

PLASTICITY  
INDEX  
PCT

FLOW  
INDEX

TOUGHNESS  
INDEX

IN-SIZE

IN-SIZE

IN-SIZE

IN-SIZE

IN-SIZE

IN-SIZE

IN-SIZE

IN-SIZE

IN-SIZE

SPFCIF  
GRAVITY

IN-SIZE

ANGLE/REPOSE  
1 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
10 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
1 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
10 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
1 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
10 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
1 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
10 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
1 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
10 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
1 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
10 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
1 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
10 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
1 IN DROP  
DEGREES AT  
PCT MOIST

ANGLE/REPOSE  
10 IN DROP  
DEGREES AT  
PCT MOIST

ST-1

CURRENT: 1 SEPT. 1972



## KEY

19A

## TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR
5FTX10	ARCH BACK	+0.5PCT	7	X		24 IN	40	NONE	WATER PUMP
FT 1.5IN									4 IN 2 IN
HAULAGE SYSTEM		PERSONNEL		SUPPLY		BOLT, TYPE SIZE		SET, SIZE, SHAPE	
MUCK	60 CF SIDE DUMP	RAIL		RAIL		6FTX.75IN	4/ MAT	9FTX13IN MATS	SHOTCRETE
40 LB RAIL						21 BACK, 21		EACH RIB	
24 IN GAGE									
6 T MOTOR									

## MACHINE EXCAVATION

MACHINE	MAKE	MODEL	WT	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	INTERIOR	GAGE	RPM	TORQUE, MAX/OPERATE	HEAD, CENTER	THRUST, MAX/OPERATE
									KFTLB KFTLB	KLB KLB

ANCHOR	PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/50 FT
					KLB

## CONVENTIONAL EXCAVATION

MACHINE	JUMBO	3 BOOM	MACHINES	2-S83F	1-D99	FEED LENGTH	8FT
ROUND, NO. HOLES	44	DEPTH	7 FT	DIAM.	1 5/8 IN	CUT, BURN	2-4 IN
EXPLOSIVES, POWDER FACTOR	5.4LB/CY	TOTAL LBS	125	PRIMERS,	25LBS	60WR	1X16 IN
BLASTING ELECTRICAL	ATLAS-COPCO	DELAYS	0-14 REGULAR				
MUCKING	ATLAS-COPCO	LM56					
GUIDANCE	TRANSIT						

ST-1

CURRENT: 09/01/72

KEY IDENTIFICATION 20 CR  
 ROCK PROPERTIES  
 METAMORPHIC: QUARTZITE  
 MODERATELY FOLDED  
 MODERATELY TO HIGHLY FRACTURED  
 VEINLET, DIPPING 75-90 DEGREES  
 SAMPLE NO CR-1  
 DRY WT PCF 50  
 COMPR STRNTH KPSI NA  
 ROD PCT EST 50  
 SHORE MDH SCHMIDT NA  
 HARDNESS  
 MOISTURE PCT(+16) 6IN. 3IN. 2IN. 1IN. 1/2IN. ND4 . NO8 ND16 ND30 NOS0 NO100 ND20J PCT (-) ND200

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

POT VOL CHANGE (-) IN.SIZE  
 LIQUID LIMIT PCT  
 PLASTIC LIMIT PCT  
 SHINKAGE LIMIT PCT  
 ATTERBERG LIMITS..SIZE(-) IN..  
 PLASTICITY INDEX  
 FLOW INDEX  
 TOUGHNESS INDEX  
 SPECIFIC GRAVITY IN.SIZE  
 ANGLE/REPOSE 1 IN DROP DEGREES AT PCT MOIST  
 MATERIAL SIZE(-) IN..  
 ANGLE/SLIDE STEEL PLATE DEGREES AT PCT MOIST  
 APPARENT COHESION PSF AT PCT MOIST  
 BULK DENSITY PCF AT PCT MOIST  
 SIZE(-) IN..  
 ANGLE INTER FRICTION DEGREES AT PCT MOIST

CR-1 CURRENT: 1 SEPT. 1972



KEY IDENTIFICATION  
21 HOME STAKE

ROCK PROPERTIES  
METAMORPHIC: PHYLLITE WITH  
VEINQUARTZ, CHLORITE SCHIST  
HIGHLY METAMORPHOSED AND  
FOLDED. WITH MINOR FAULTING

MOISTURE PCT (-) 16  
IN. SIZE 6 IN. 3 IN. 2 IN. 1 IN. 1/2 IN. NO. 4 NO. 8 NO. 16 NO. 30 NO. 50 NO. 100 NO. 200 PCT (-) NO. 200

SHORE MOH SCHMIOT

COMPR STRNTH KPSI

DRY WT PCF

187 19 70 NA

2.2 25.3 1.5 9.2 13.2 13.3 10.4 3.2 2.0 1.2 0.7 0.5 0.5 3.0

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

POT VOL CHANGE (-) 0.054 IN. SIZE

LIQUID LIMIT PCT

19.80

16.06

15.12

2.74

2.70

1.01

SIZE (-) 12.0 IN. ANGLE INTER FRICTION DEGREES AT 2.0 PCT MOIST

SIZE (-) 12.0 IN. ANGLE INTER FRICTION DEGREES AT 2.0 PCT MOIST

2.84 40 34 31 160 99 39

HS-I CURRENT: 1 SEPT. 1972

**21A**  
**TUNNEL DATA**

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	MP	AIR	WATER	PUMP
75 FT 6 IN	16 IN 30	7K	X				2 IN	2 IN	
8 FT 6 IN									
HAULAGE SYSTEM		SUPPORT SYSTEM		ROOF PLATE		SET, SIZE, SHAPE		SHOTCRETE	
PERSONNEL	SUPPLY								
RAIL	RAIL								
1-ST POKKER									
CARS 40LB RAIL									
18 IN GAGE									
6 OR 8 T MOTORS									

## MACHINE EXCAVATION

[illegible]

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/50 FT
KL8				KL8

## CONVENTIONAL EXCAVATION

MACHINE	EXPLOSIVES,	BLASTING	MUCKING
JUMBO AIR LEG	POWDER FACTOR 7.0 LB/CY	ELECTRICAL	EIMCO
MACHINES 3IN JACK	TOTAL LAS 140	7-MILLESECOND	21
	PRIMERS, 1/2LB. 60 PCT 1X6 IN	10-REGULAR	
	TRIM ANFO		
	INTERIOR ANFO		
	CUT ANFO		
	LIFTERS ANFO		
FEED LENGTH 6FT			

KEY IDENTIFICATION  
22 NEW YORK  
SAMPLE NO  
NY-1

ROCK PROPERTIES  
METAMORPHIC: MICA SCHIST  
OCCASIONAL QUARTZ  
LAMINATIONS

ORY WT PCF NA  
COMPR STRNTH KPSI NA  
RQD PCT EST 80  
SHORE MOH SCHMIDT NA

# MUCK DATA

DRY UNIT WT PCF  
MOISTURE PCT IN-SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 PCT (-) NO200

101 12.4 0 0 0 3.5 21.9 12.3 6.6 7.5 5.3 7.5 11.7 7.7 16.0

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATEO SP=SPHEROID

PAI PA PA PA PA AI A-P A-P A

POT VOL CHANGE (-) IN-SIZE

LIQUID LIMIT PCT  
PLASTIC LIMIT PCT  
SHRINKAGE LIMIT PCT  
PLASTICITY IN. INDEX  
FLOW INDEX TOUGHNESS INDEX

(-) SPECIF GRAVITY

IN-SIZE ANGLE/REPOSE 1 IN DRIP DEGREES AT PCT MOIST  
ANGLE/REPOSE 10 IN DRIP DEGREES AT PCT MOIST  
MATERIAL SIZE (-) ANGLE/SLT OF STEEL PLATE DEGREES AT PCT MOIST  
APPARENT COHESION PSF AT PCT MOIST  
BULK DENSITY PCF AT PCT MOIST  
SIZE (-) ANGLE INTER FRICTION DEGREES AT PCT MOIST

NY-1 CURRENT: 1 SEPT. 1972

## KEY

22A  
TUNNEL DATA

TUNNEL	VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	GRADE	CFM	PRESS EXHST	SIZE	HP	AIR	WATER PUMP	PRIMARY SECONDARY
11 FT	-0.03PCT	36K	X	20 IN	40	4 IN	4 IN	6600 440
6 IN								
HAULAGE SYSTEM		PERSONNEL		SUPPORT SYSTEM		SET SIZE SHAPE		
MUCK	RAIL	SUPPLY	RAIL		BOLT TYPE SIZE		ROOF PLATE	
17CY CAPS								
10T MOTORS								
70LB RAIL								
36 IN GAGE								

## MACHINE EXCAVATION

MACHINE	CUTTERS MAKE TYPE DIAM CUTTING EDGES		RPM	TORQUE MAX/OPERATE	THRUST MAX/OPERATE
MAKE	MODEL	WT	HEAD CENTER	HEAD	CENTER
JARVA	12-110	NA	NA	KFTLBNA	KFTLB
				KFTLB	KFTLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/50 FT
KLB	RUCKETS TO	NA	LASER	KLB
	BELT			

## CONVENTIONAL EXCAVATION

MACHINE	ROUND	EXPLOSIVES	BLASTING	MUCKING	GUIDANCE
JUMBO	NO. HOLES	POWDER FACTOR			
MACHINES	DEPTH	TOTAL LBS			
	DIAM.	PRIMERS			
	CUT	TRIM			
		INTERIOR			
		CUT			
		LIFTERS			

## FEED LENGTH

NY-1 CURRENT: 09/31/72

KEY IDENTIFICATION  
23 NEW YORK  
SAMPLE NO  
NY-2

ROCK PROPERTIES  
METAMORPHIC: MICA SCHIST  
OCCASIONAL QUARTZ  
LAMINATIONS

ORY  
WT  
PCF  
NA

COMPR  
STRNTH  
KPSI  
NA

RQD  
PCT  
EST  
90

SHORE  
MOH  
SCHMIDT  
NA

MUCK DATA  
DRY UNIT  
WT PCF

MOISTURE PCT 1-16  
IN-SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200

PER CENT BY WEIGHT BETWEEN SCREENS.....

7.2 0 0 0 2.2 13.3 10.6 5.0 9.2 6.5 9.1 14.6 9.5 19.0

PCT (-)  
NO200

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PAI PA PA PA AI AI A-P A-P A

POT VOL CHANGE  
(-)  
IN-SIZE

LIQUID LIMIT PCT

PLASTIC LIMIT PCT

SHRIMPAGE LIMIT PCT

PLASTICITY INDEX PCT

FLOW INDEX

TOUGHNESS INDEX

(-) IN-SIZE  
SPECIFIC GRAVITY

ANGLE/REPOSE 1 IN DROP DEGREES AT PCT MOIST

ANGLE/REPOSE 10 IN DROP DEGREES AT PCT MOIST

ANGLE/SLIOE STEEL PLATE DEGREES AT PCT MOIST

APPARENT COMESION PSF AT PCT MOIST

BULK DENSITY PCF AT PCT MOIST

SIZE(-)  
IN. ANGLE INTER FRICTION DEGREES AT PCT MOIST

NY-2 CURRENT: 1 SEPT. 1972



**23A**  
**TUNNEL DATA**

## TUNNEL

SIZE	SHAPE
8 FT	ROUND
6 IN	

## HAULAGE SYSTEM

MUCK  
RAIL  
113 CY CARS  
110 T MOTORS  
770 LA RAIL  
336 IN GAGE

## PERSONNEL RAIL

**SUPPLY  
RAIL**

**BOLT, TYPE SIZE ROOF PLATE**

## VENTILATION

PRESS	EXHST	SIZE	HP
X		12 IN	40

## WATER TREATMENT

**GPM**  
**26**

UNIT 11: TUESDAY

AIR WATER PUMP  
4 IN 4 IN 4 IN

**DATA SYSTEM**

PRIMARY	SECONDARY
660C	440

## MACHINE EXCAVATION

**MACHINE**

MAKE	MODEL	WT
JARVA	S-806	NA

**CUTTERS • MAKE • TYPE • U.I.A. • CUTTING • EDGES**

CENTER  
2 REO  
TOOTH TYPE

## RPM

HEAD.CENTER NA	HEAD
KFTLBNA	
KFTLB	

**TORQUE, MAX/OPERATE**

HEAD	CENTER
KFTLBNA	KFTLB
KFTLB	KFTLB

**THRUST, MAX/OPERATE**

KL8 NA  
KL8

ANCHOR PRESS MUCK SYSTEM  
BUCKETS  
TO BELT  
KLB

**POWER SYSTEM**  
**NA**

GUIDOANCE  
LASER

## CONVENTIONAL EXCAVATION

**MACHINE  
OR  
MACHINES**

ROUND.	NO. HOLES	DEPTH	DIAM.	CUT.
1	1	10	1/2	1/2
2	1	10	1/2	1/2
3	1	10	1/2	1/2
4	1	10	1/2	1/2
5	1	10	1/2	1/2
6	1	10	1/2	1/2
7	1	10	1/2	1/2
8	1	10	1/2	1/2
9	1	10	1/2	1/2
10	1	10	1/2	1/2
11	1	10	1/2	1/2
12	1	10	1/2	1/2
13	1	10	1/2	1/2
14	1	10	1/2	1/2
15	1	10	1/2	1/2
16	1	10	1/2	1/2
17	1	10	1/2	1/2
18	1	10	1/2	1/2
19	1	10	1/2	1/2
20	1	10	1/2	1/2
21	1	10	1/2	1/2
22	1	10	1/2	1/2
23	1	10	1/2	1/2
24	1	10	1/2	1/2
25	1	10	1/2	1/2
26	1	10	1/2	1/2
27	1	10	1/2	1/2
28	1	10	1/2	1/2
29	1	10	1/2	1/2
30	1	10	1/2	1/2
31	1	10	1/2	1/2
32	1	10	1/2	1/2
33	1	10	1/2	1/2
34	1	10	1/2	1/2
35	1	10	1/2	1/2
36	1	10	1/2	1/2
37	1	10	1/2	1/2
38	1	10	1/2	1/2
39	1	10	1/2	1/2
40	1	10	1/2	1/2
41	1	10	1/2	1/2
42	1	10	1/2	1/2
43	1	10	1/2	1/2
44	1	10	1/2	1/2
45	1	10	1/2	1/2
46	1	10	1/2	1/2
47	1	10	1/2	1/2
48	1	10	1/2	1/2
49	1	10	1/2	1/2
50	1	10	1/2	1/2
51	1	10	1/2	1/2
52	1	10	1/2	1/2
53	1	10	1/2	1/2
54	1	10	1/2	1/2
55	1	10	1/2	1/2
56	1	10	1/2	1/2
57	1	10	1/2	1/2
58	1	10	1/2	1/2
59	1	10	1/2	1/2
60	1	10	1/2	1/2
61	1	10	1/2	1/2
62	1	10	1/2	1/2
63	1	10	1/2	1/2
64	1	10	1/2	1/2
65	1	10	1/2	1/2
66	1	10	1/2	1/2
67	1	10	1/2	1/2
68	1	10	1/2	1/2
69	1	10	1/2	1/2
70	1	10	1/2	1/2
71	1	10	1/2	1/2
72	1	10	1/2	1/2
73	1	10	1/2	1/2
74	1	10	1/2	1/2
75	1	10	1/2	1/2
76	1	10	1/2	1/2
77	1	10	1/2	1/2
78	1	10	1/2	1/2
79	1	10	1/2	1/2
80	1	10	1/2	1/2
81	1	10	1/2	1/2
82	1	10	1/2	1/2
83	1	10	1/2	1/2
84	1	10	1/2	1/2
85				

EXPLOSIVES,  
POWDER FACTOR  
TOTAL LBS  
PRIMERS,  
TRIM  
INTERIOR  
CUT  
LIFTERS

## BLASTING

## MUCKING

## GUIDANCE

## FREE LENGTH

KEY IDENTIFICATION  
24 QUEEN LANE

ROCK PROPERTIES

METAMORPHIC: GRAY MICA SCHIST  
OCCASIONAL QUARTZ SEAMS, MICA  
VARIES FROM DENSE, FINE  
GRAINED TO EXTREMELY COARSE.

SHORE MOH SCHMIDT

COMPR STRNTH  
KPSI

ORY WT PCF

SAMPLE NO  
QL-1

165 30 NA NA NA

MUCK DATA

DRY UNIT MOISTURE PCT(1)16 \*.....PER CENT HY WEIGHT BETWEEN SCREENS..... PCT (-)  
WT PCF PCT IN.SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NOSO NO100 NO200 NO200

108 9.0 0.0 0.0 0.0 7.6 17.0 13.4 4.5 4.9 5.4 8.4 10.2 7.7 20.9

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

B-47

POT VOL CHANGE  
(-10.056 IN.SIZE

LIQUID LIMITS PCT \*.....ATTERBERG LIMITS..SIZE(-) 0.056IN.....  
PLASTIC LIMIT SHRINKAGE PLASTICITY FLOW TOUGHNESS  
PCT PCT PCT INDEX INDEX

0 24.0 23.3 22.7 0.7 4.0 0.17

(-10.75 IN.SIZE  
SPECIFIC GRAVITY

ANGLE/REPOSE \*.....MATERIAL SIZE(-)2.0 IN.....  
1 IN DROP ANGLE/REPOSE ANGLE/SLIDE APPARENT BULK  
DEGREES AT 10 IN DROP STEEL PLATE COMESION DENSITY  
9.8 PCT MOIST 9.8 PCT MOIST 8.4 PCT MOIST 9.3 PCT MOIST 0.0 PCT MOIST 9.3 PCT MOIST

2.57 39 37 40 125 75 30

QL-1 CURRENT: 1 SEPT. 1972

## KEY

24A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE 11FT.	SHAPE ROUND	GRADE +1-3PCT	CFM 4K	PRESS EXHST X	SIZE 14IN	HP	GPM	AIR WATER PUMP 4IN	PRIMARY SECONDARY 4160V 480V
HAULAGE SYSTEM		PERSONNEL RAIL		SUPPLY RAIL		SUPPORT SYSTEM		SET, SIZE, SHAPE OCCASIONAL SEMI- CIRCULAR PLATES PINNED AT SPING LINE AT FAULTS	
MUCK RAIL		BOLT, TYPE SIZE		ROOF PLATE		SHOTCRETE			

## MACHINE EXCAVATION

MACHINE		CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES		RPM		TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MAKE JARVA	MODEL MARK 11-1100	WT 70 TONS	CENTER 2 REED STEEL TRIPLE DISC	INTERIOR 26 REED STEEL TRIPLE DISC	GAGE 6 REED STEEL TRIPLE DISC	HEAD, CENTER 10.75INTEG	HEAD KFTLB 244 KFTLB	CENTER KFTLB KFTLB	KLB 377

ANCHOR PRESS		MUCK SYSTEM		POWER SYSTEM		GUIDANCE		THRUST/50 FT	
KLB 3402	BUCKET FROM FACE, CONVEYOR BELT TO REAR	4-125HP ELECT, MOTORS, 40HP MOTORS, HYDRAULIC	LASER	KLB 3.53					

## CONVENTIONAL EXCAVATION

MACHINE JUNBO MACHINES		ROUND, NO. HOLES DEPTH DIAM. CUT,		EXPLOSIVES, POWDER FACTOR TOTAL LBS PRIMERS, TRIM INTERIOR CUT LIFTERS		BLASTING		MUCKING		GUIDANCE	
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FEED LENGTH

OL-1

CURRENT: 09/01/72

# KEY IDENTIFICATION

25 MB  
SAMPLE NO  
MB-2

## ROCK PROPERTIES

SEDIMENTARY, GRAYWACKE  
(ARGILLACEOUS QUARTZITE)  
MASSIVE TO MEDIUM BEDDED,  
HIGHLY FOLDED AND FRACTURED  
NORMAL DIP OF BEDDING  
30 DEGREES TO 45 DEGREES

DY  
WT  
PCF

COMPR  
STRNTH  
KPSI

RQD  
PCT

SHORE MOH  
HARDNESS

MUCK DATA  
DRY UNIT  
WT PCF

MOISTURE  
PCT

IN SIZE  
PCT

6 IN. 3 IN. 2 IN. 1 IN. 1/2 IN. NO4

PER CENT BY WEIGHT BETWEEN SCREENS

NO16 NO8

NO30 NO50 NO100 NO200

PCT (-)

NO200

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATE C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

POT VOL CHANGE  
(-)  
IN SIZE

LIQUID  
LIMITS  
PCT

PLASTIC  
LIMIT  
PCT

SHRINKAGE  
LIMIT  
PCT

PLASTICITY  
INDEX  
PCT

FLOW  
INDEX

TOUGHNESS  
INDEX

SPECIFIC  
GRAVITY

IN SIZE  
ANGLE/REPOSE  
1 IN OROP  
DEGREES AT  
PCT MOIST

MATERIAL SIZE (-)  
ANGLE/REPOSE  
10 IN OROP  
DEGREES AT  
PCT MOIST

APPARENT  
COMPRESSION  
PSF AT  
PCT MOIST

BULK  
DENSITY  
PCF AT  
PCT MOIST

SIZE (-)  
ANGLE INTER  
FRICTION  
DEGREES AT  
PCT MOIST

MB-2

CURRENT: 1 SEPT. 1972

25A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	AIR	WATER PUMP
10 FT	RECT	-2.0	PCT BK	X	16 IN	30	NONE	6 IN	4 IN
10.8 FT									
HAULAGE SYSTEM									
PERSONNEL		SUPPLY		BOLT, TYPE		SIZE		ROOF PLATE	
RAIL		RAIL		6 FT X		.75 IN		AS REQUIRED	
SHOTCRETE									
SET, SIZE, SHAPE									
MUCK									
RAIL 140-200CF									
BOTTOM DUMPCARS									
60-80LB RAIL									
10T MOTOR									
30 IN GAGE									

## MACHINE EXCAVATION

MACHINE	MAKE	MODEL	WT	CUTTERS•MAKE•TYPE•DIAM•CUTTING EDGE'S	RPM	TORQUE•MAX/OPERATE	THRUST•MAX/OPERATE
				CENTER <td>INTERIOR<td>GAGE<td></td></td></td>	INTERIOR <td>GAGE<td></td></td>	GAGE <td></td>	
				HEAD•CENTER <td>HEAD<td>CENTER<td></td></td></td>	HEAD <td>CENTER<td></td></td>	CENTER <td></td>	
					KFTLB	KFTLB	KLB
					KFTLB	KFTLB	KLB

ANCHOR	PRESS	MUCK	SYSTEM	POWER	SYSTEM	GUIDANCE	THRUST/SQ FT
KL8							414

## CONVENTIONAL EXCAVATION

MACHINE	ROUND.	EXPLOSIVES.	BLASTING	MUCKING	GUIDANCE
JUNBO 2	NO. HOLES 36	POWDER FACTOR 7.5LB/CY	IGNITER CORD	EIMCO	TRANSIT
MACHINES	DEPTH 8 FT	TOTAL LBS 210	FUSE, CAPS	40	
	D-93	PRIMERS, 10LB. 70PCT 7/8X8 IN	DEIAPRIME		
ROUND	DIAM. 1 5/8IN	TRIM ANFO			
1 1/4 STEEL	CUT, V	INTERIOR ANFO			
FEEO LENGTH 10FT		CUT ANFO			
		LIFTERS ANFO			

# KEY IDENTIFICATION

## ROCK PROPERTIES

26 S-1  
 DRY UNIT  
 SAMPLE NO  
 S-1

SEOTMENTARY: SANDSTONE FINE  
 GRAINED, WELL COMPACTED,  
 LIGHT BROWN OVER 50 PCT  
 QUARTZ.

OR  
 WT  
 PCF

CUMPR  
 STNTH  
 KPSI

RQD  
 PCT

SHORE  
 MOH

SCHMIDT

NA

61

92

22

166

## MUCK DATA

DRY UNIT  
 WT  
 PCF

MOISTURE  
 PCT

PCT(+)6  
 IN-SIZE

PER CENT BY WEIGHT BETWEEN SCREENS.....

NO4  
 NO8  
 NO16  
 NO30  
 NO50  
 NC100  
 NC200

NO4  
 NO8  
 NO16  
 NO30  
 NO50  
 NC100  
 NC200

NO4  
 NO8  
 NO16  
 NO30  
 NO50  
 NC100  
 NC200

NO4  
 NO8  
 NO16  
 NO30  
 NO50  
 NC100  
 NC200

NO4  
 NO8  
 NO16  
 NO30  
 NO50  
 NC100  
 NC200

NO4  
 NO8  
 NO16  
 NO30  
 NO50  
 NC100  
 NC200

NO4  
 NO8  
 NO16  
 NO30  
 NO50  
 NC100  
 NC200

NO4  
 NO8  
 NO16  
 NO30  
 NO50  
 NC100  
 NC200

83

5.4

0.0

0.0

0.0

0.0

0.0

0.0

0.0

0.0

0.0

0.0

0.0

0.0

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PI

PI

PI

PI

PI

PI

PI

PI

PI

PI

PI

PI

POT VOL CHANGE  
 (-)0.065 IN-SIZE

LIQUID  
 LIMITS  
 PCT

PLASTIC  
 LIMIT  
 PCT

SHRINKAGE  
 LIMIT  
 PCT

ATTERBERG LIMITS..SIZE(+) 0.185IN..

PLASTICITY  
 INDEX  
 PCT

FLOW  
 INDEX

TOUGHNESS  
 INDEX

TOUGHNESS  
 INDEX

TOUGHNESS  
 INDEX

0

16.40

15.50

15.50

15.50

15.50

15.50

15.50

15.50

15.50

15.50

15.50

15.50

15.50

(-)0.75 IN-SIZE  
 SPECIFIC  
 GRAVITY

ANGLE/REPOSE  
 1 IN DROP  
 DEGREES AT

ANGLE/REPOSE  
 10 IN DROP  
 DEGREES AT

ANGLE/REPOSE  
 10 IN DROP  
 DEGREES AT

ANGLE/REPOSE  
 10 IN DROP  
 DEGREES AT

ANGLE/REPOSE  
 10 IN DROP  
 DEGREES AT

ANGLE/REPOSE  
 10 IN DROP  
 DEGREES AT

ANGLE/REPOSE  
 10 IN DROP  
 DEGREES AT

ANGLE/REPOSE  
 10 IN DROP  
 DEGREES AT

ANGLE/REPOSE  
 10 IN DROP  
 DEGREES AT

2.73

35

29

28

NA

NA

29

S-1

CURRENT: 1 SEPT. 1972

## KEY

26A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR
18 FT	ROUND	-7.0PCT	17K		X	36IN	75	5-10	2IN
1 IN									4IN
HAULAGE SYSTEM		PERSONNEL		SUPPLY		BOLT, TYPE SIZE		SET, SIZE, SHAPE	
MUCK	30IN PIGGYBACK	DIESEL				4-5/8IN X 4FT		8.2LB CHANNEL	SHOTCRETE
	CONVEYORS, 36IN	TRUCKS,						6IN X 9.5FT OR	
	SUSPENDED	JEEPS						13.5FT AT 4FT	
	CONVEYOR							OR 2FT	

## MACHINE EXCAVATION

MACHINE	MAKE	MODEL	WT	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRL ST, MAX/OPERATE
KOBINS	KOBINS	181-122	260 TONS	CENTER 1 ROBBINS, 7.5IN TRIPLE STEEL DISC	HEAD, CENTER 4.5 INTEG	HEAD KFTLB1720 KFTLB	CENTER KFTLB KFTLB
				GAGE 3 ROBBINS, 12IN STEEL DISC			KLB 1580 KLB 914

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THPUSH/50 FT
KLB	BUCKETS FROM FACE, 30IN CONVEYOR TO REAR	6-250HP MOTORS FOR HEAD	LASER	KLB 3.56

## CONVENTIONAL EXCAVATION

MACHINE	ROUND,	EXPLOSIVES,	BLASTING	MUCKING	GUIDANCE
JUMBO	NO. HOLES	POWDER FACTOR			
MACHINES	DEPTH	TOTAL LBS			
	DIAM.	PRIMERS,			
	CUT,	TRIM			
		INTERIOR			
		CUT			
		LIFTERS			

## FEED LENGTH

5-1 CURRENT: 09/01/72

KEY IDENTIFICATION  
27 7-2

ROCK PROPERTIES  
SEDIMENTARY: SANDSTONE FINE  
GRAINED, WELL COMPACTED,  
LIGHT BROWN, OVER 50 PCT  
QUARTZ.

COMPR STRENGTH  
KPSI

ROD PCT

.....HARDNESS.....  
SI RE MOH SCHMIDT

SAMPLE NO  
7-2

DRY  
WT

PCF

166

61

NA

MUCK DATA

DRY UNIT  
WT PCF

MOISTURE  
PCT

.....PER CENT BY WEIGHT BETWEEN SCREENS.....  
IN-SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4

NO8

NO16

NO30

NO50

NO100

NO200

PCT (-)

NO200

90 4.0 0.0

1.5

0.9

33.1

22.6

15.4

4.3

2.6

1.4

1.2

2.5

3.8

10.7

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

POT VOL CHANGE  
(-10.056 IN-SIZE

LIQUID  
LIMITS

PLASTIC  
LIMIT

SHRINKAGE  
LIMIT

PLASTICITY  
INDEX

0.050IN.

TOUGHNESS  
INDEX

FLOW  
INDEX

0.78

6.90

5.37

17.58

23.0

(-10.75 IN-SIZE  
SPFCIF  
GRAVITY

ANGLE/REPOSE  
1 IN DROP

DEGREES AT  
2.6 PCT MOIST

10 IN DROP  
DEGREES AT

ANGLE/SLIDE  
STEEL PLATE

2.6 PCT MOIST

2.6 PCT MOIST

2.6 PCT MOIST

2.6 PCT MOIST

2.6 PCT MOIST

2.6 PCT MOIST

2.6 PCT MOIST

2.6 PCT MOIST

2.63

32

31

29

0

92.8

44

7-2

CURRENT: 1 SEPT. 1972



KEY

27A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM					
SIZE	SHAPE	GRAPE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR	WATER	PUMP	PRIMARY	SECONDARY
18FT	ROUND	•2.0PCT	17K		X	36IN	75	5-10	2IN	4IN		4160V	480V
1IN													

HAULAGE SYSTEM

PERSONNEL  
30IN P.GGYBACK  
CONVEYOR, 36IN  
SUSPENDED  
CONVEYOR

SUPPORT SYSTEM

BOLT-TYPE SIZE  
4-5/8IN X 4FT  
ROOF PLATE  
8-2LB CHANNEL  
6IN X 9.5FT OR  
13.5FT AT 4FT  
OR 2FT

SET-SIZE-SHAPE

SHOTCRETE

MACHINE EXCAVATION

MACHINE	MAKE	MODEL	WT	CUTTERS-MAKE-TYPE, DIAM, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
ROBBINS	181-122	260	TONS	CENTER 1 ROBBINS 7.5IN TRIPLE STEEL DISC	HEAD, CENTER 4.5	HEAD KFTLB 1720 KFTLB	CENTER KFTLB 1580 KFTLB 747

ANCHOR PRESS  
BUCKETS FROM  
FACE, 30IN  
CONVEYOR TO  
REAR

POWER SYSTEM  
4-200HP MOTORS  
FOR HEAD

GUIDANCE  
LASER

THRUST/50 FT  
KLB 2.91

CONVENTIONAL EXCAVATION

MACHINE	ROUND	NO. HOLES	DEPTH	DIAM.	CUT.	EXPLOSIVES,	POWDER FACTOR	TOTAL LBS	PRIMERS,	TRIM	INTERIOR	CUT	LIFTERS
JUNBO													
MACHINES													
FEED LENGTH													

BLASTING

MUCKING

GUIDANCE

# KEY IDENTIFICATION 28, 11-3

ROCK PROPERTIES  
SEDIMENTARY: SHALE, MASSIVE TO  
THINLY LAMINATED. INTERBEDDED  
SILTSTONE AND SHALE, WITH  
MINOR SANDSTONE AND LIMESTONE  
LAYERS. GRAIN SIZE FINE TO  
COARSE. QUARTZ 24 TO 33 PCT.

SAMPLE NO  
11-3

DRY  
WT  
PCF

COMPR  
STRNTH  
KPSI

ROD  
PCT  
EST

SHORE  
MOH

HARNESS  
SCHMIDT

90 NA NA  
PARALLEL  
41-55.  
NORMAL  
41-54.

4 MAJOR BEGS  
22 TO 29.  
3 MINOR BEDS  
12 TO 17.  
WT. AVE 23

## MUCK DATA

DRY UNIT WT PCF 1.1 7.8 12.6 11.3 14.4 14.9 16.4 5.7 3.5 2.0 1.4 1.1 0.9 8.0

MOISTURE PCT 1.1 7.8 12.6 11.3 14.4 14.9 16.4 5.7 3.5 2.0 1.4 1.1 0.9 8.0

PER CENT BY WEIGHT BETWEEN SCREENS..... PCT (-) NO200

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATEO SP=SPHEROID

PA PA PA PA PA PA PA A A A A A

POT VOL CHANGE  
(-)-10.056 IN-SIZE

LIQUID LIMIT PCT 15.60 14.81 14.51 0.79 3.00 0.26

PLASTIC LIMIT PCT 14.81 14.51 0.79 3.00 0.26

SHRINKAGE LIMIT PCT 14.51 0.79 3.00 0.26

PLASTICITY INOEY INOEY INOEY

TOUGHNESS INOEY

(-)-10.75 IN-SIZE  
SPFCIF GRAVITY

ANGLE/REPOSE 1 IN OPOP  
DEGREES AT 1.0 PCT MOIST

ANGLE/REPOSE 10 IN DROD  
DEGREES AT 1.0 PCT MOIST

ANGLE/SLIDE STEEL PLATE  
DEGREES AT 1.0 PCT MOIST

APPARENT COMESION PSF AT 0.2 PCT MOIST

BULK DENSITY PCF AT 0.2 PCT MOIST

2.65

25

25

29

550

100

46

KEY

28A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	CFM	PRESS EXIST	SIZE	HP	GPM	AIR WATER PUMP	PRIMARY	SECONDARY
24FT X 7	RECT	80-100K	X			NONE	4IN 4IN 4IN		110V
HAULAGE SYSTEM		SUPPORT SYSTEM							
WICK	PERSONNEL	BOLT TYPE SIZE		ROOF PLATE		SET SIZE SHAPE		SHOTCRETE	
WAGNER ST-5	DIESEL	5/8IN X 6FT		11IN X 10FT					
SCOOPTRAM	TRUCKS	4FT X 4FT		PATTERN					
LATON SHUTTLE	JEEPS								
CARS									

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
MAKE	CENTER	HEAD, CENTER	HEAD	CENTER
MODEL	INTERIOR	KFTLB	KFTLB	KLB
		KFTLB	KFTLB	KLB

ANCHOR PRESS MUCK SYSTEM POWER SYSTEM GUIDANCE THRUUST/SQ FT

KLB KLB

CONVENTIONAL EXCAVATION

MACHINE	ROUND	EXPLOSIVES	BLASTING	MUCKING	GUIDANCE
JUNBO 2 800N HYDROJIB	NO. HOLES 35	POWDER FACTOR 3.5LB/CY	ELECTRICAL	SCOOPTRAM	TRANSIT
MACHINES 2-AR93	DEPTH 10.5FT - 11FT	TOTAL LBS 234	M.S. DELAYS		LASER
ORIFTERS	DIAM. 1-3/4IN	PRIMERS, 16LB 1.25IN X 8IN, 75PCT			
FEED LENGTH 14FT	CUT. V	TRIM 11LB 1.25IN X 12IN, COALITE 5Y			
	1-6FT BUSTEN	INTERIOR ANFO			
	HOLE	CUT			
	SF./HOLE 5.1	LIFTEMS 32LB 1.25IN X 12IN, RXL 60PCT			

11-3 CURRENT: 09/01/72

# KEY IDENTIFICATION

29 11-4

## ROCK PROPERTIES

SEDIMENTARY: SHALE, MASSIVE TO THINLY LAMINATED, INTERBEDDED SILTSTONE AND SHALE WITH MINDR SANDSTONE AND LESTONE LAYERS GRAIN SIZE FINE TO COARSE, QUARTZ 24 TO 33 PCT.

DRY WT PCT

CDMPR STRNTH KPSI

RQD EST

SHORE MOH SCHMIDT

HARDNESS

SAMPLE NC 11-4

166 4 MAJOR BEDS 22 TO 29. 3 MINOR BEDS 12 TO 17. WT. AVE 22 .

90 PARALLEL 41-SS. NORMAL 41-54.

NA NA

## MUCK DATA

DRY UNIT WT PCT MOISTURE PCT(+)16 IN.SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 ND8 ND16 ND30 ND50 ND100 ND200 PCT (-) ND200

96 1.1 9.2 17.7 17.0 19.3 15.7 12.7 3.4 2.5 1.2 0.6 0.2 0.2 1.3

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

POT VOL CHANGE (-)0.056 IN.SIZE

LIQUID LIMIT PCT 15.80 PLASTIC LIMIT PCT 15.60 SHRINKAGE LIMIT PCT 13.26 ATTERBERG LIMITS SIZE (-) 0.056IN. PLASTICITY INDEX PCT 0.20 FLOW INDEX PCT 0.05 TOUGHNESS INDEX

0.

(-)0.75 IN.SIZE SPECIF GRAVITY

ANGLE/REPOSE 1 IN DROP DEGREES AT 0.9 PCT MOIST 0.9 PCT MOIST 0.9 PCT MOIST MATERIAL SIZE (-)2.0 IN. ANGLE/SLIDE STEEL PLATE DEGREES AT 0.9 PCT MOIST 0.2 PCT MOIST 0.0 PCT MOIST 0.2 PCT MOIST APPARENT COMESION PSF AT 0.2 PCT MOIST 0.0 PCT MOIST BULK DENSITY PCF AT 0.2 PCT MOIST

SIZE (-)2.0 IN. ANGLE INTER FRACTION DEGREES AT 0.2 PCT MOIST

2.79

29

29

28

282

100

54

## KEY

29A  
TUNNEL DATA

TUNNEL	VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS EXHST	SIZE	HP	GPM	AIR WATER PUMP
19FTx8	RECT	0.0	20K	ENTRY FACE		40	NONE	2IN
.SFT								
HAULAGE SYSTEM	PERSONNEL		SUPPLY		BOLT, TYPE SIZE		ROOF PLATE	
MUCK	DIESEL SHUTTLE	DIESEL	TRUCK	TRUCK	5/8IN X 6FT AT	4FT X 4FT		SHOTCRETE
CAR, CONVEYOR								

## MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES		RPM	TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD	CENTER
ATLAS -	4-HEAD	180	48 T.C. ORAG	CUTTERS MOUNTED ON 4	ROTATING	KFTLB	KFTLB
COPCO		L.T.	HEADS			KFTLB	KFTLB
							KLB 1.093
							KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/50 FT
KLB 1000	FLIGHT CONVEYOR	4-60KW MOTORS	TRANSIT	
	STAR WHEEL,	HEAD ROTATION	LASER	KLB
	25IN CONVEYOR	2-78KW MOTORS		
		HYDRAULICS		

## CONVENTIONAL EXCAVATION

MACHINE	ROUND	EXPLOSIVES,	BLASTING	MUCKING	GUIDANCE
JUMBO	NO. HOLES	POWDER FACTOR			
MACHINES	DEPTH	TOTAL LBS			
	DIAM.	PRIMERS,			
	CUT,	TRIM			
		INTERIOR			
		CUT			
		LIFTERS			

## FEED LENGTH



30A  
TUNNEL DATA

TUNNEL		VENTILATION		*WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE 18 FT I IN	SHAPE ROUND	GRADE +10.0PCT	CFM 18K	PRESS EXHST X	AIR WATER PUMP 2 IN 4IN	PRIMARY SECONDARY 4160 480
<b>HAULAGE SYSTEM</b>						
MUCK	PERSONNEL	SUPPLY	DIESEL TRUCKS JEEPS	BOLI TYPE SIZE 6-6FTX5/8 IN	ROOF PLATE 8.2 LB CHANNEL 6 IN X9.SFT OR 13.5 FT AT 2 FT	SHOTCRETE
CONVEYOR	OIESEL TRUCKS JEEPS				SET SIZE SHAPE	
SUSPENED CONVEYOR						

# MACHINE EXCAVATION

MACHINE	CUTTERS-MAKE, TYPE, DIA., CUTTING EDGES	RPM	TORQUE, MAX./OPERATE	THRUST, MAX./OPERATE				
MAKE	MODEL	WT	INTERIOR	GAGE	HEAO, CENTER	HEAO	CENTER	
ROBBINS	181-122	260	ROBINS OISC	3 ROBBINS OISC	4.5	KFTLB1147	KFTLB	KL8
			7.5IN TRIPLE W/	12IN, ESCO RING	6	KFTLB	KFTLB	KL8 760

ANCHOR PRESS	MUCK SYSTEM BUCKETS	POWER SYSTEM 4-200 HP FOR HEAD	GUIDANCE LASER	THRUST/SQ FT KLB
KLB 1000	TO BELT			

## CONVENTIONAL EXCAVATION

MACHINE	EXPLOSIVES.
JUN90	POWDER FACTOR
MACHINES	TOTAL LBS
	PRIMERS.
	TRIM
	INTERIOR
	CUT
	LIFTERS
FEED LENGTH	

## BLASTING MUCKING GUIDANCE

KEY IDENTIFICATION  
31 MSU

ROCK PROPERTIES  
SEDIMENTARY: CONGLOMERATE  
(RRFCCIA) .25 IN TO 10 IN  
ROUNDED TO ANGULAR BOULDERS  
COBBLES, PEBBLES,  
PREDOMINATELY LIMESTONE  
MATRIX W/CHERT, SCHIST,  
DIRASE FRAGMENTS

DR:  
WT PCF 171

CUMPR  
STRNTH  
KPSI NA

ROD  
PCT EST 65

SHORE MOH SCHMIOT NA

MOISTURE PCT 5.6

PER CENT BY WEIGHT BETWEEN SCREENS.....

6IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200

17.0 12.0 24.0 18.0 16.0 4.0 3.0 2.0 1.0 0.0 2.0

104

MUCK DATA  
DPY UNIT  
WT PCF

PCT (-)

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

A A A A A A A A A A

POT VOL CHANGE  
(-)0.056 IN-SIZE

LIQUID LIMIT PCT 13.60

PLASTIC LIMIT PCT 12.77

SHRINKAGE LIMIT PCT 16.78

ATTEMPTED LIMITS SIZE (-) 0.004IN

PLASTICITY INDEX PCT 1.03

FLOW INDEX 3.20

TOUGHNESS INDEX 0.32

SIZE (-)12.0 IN.

ANGLE INTER FRICTION DEGREES AT 0.3 PCT MOIST

APPEARANT BULK DENSITY PCF AT 0.3 PCT MOIST

IN-SIZE MATERIAL SIZE (-)2.0 IN.

ANGLE/REPOSE 10 IN UROP DEGREES AT 0.4 PCT MOIST

1 IN UROP DEGREES AT 0.4 PCT MOIST

35 29 27 410 111 46

2.74

MSU-1 CURRENT: 1 SEPT. 1972



KEY

31A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	NONE
9 FT	RECT	0.0	10K	X	24 IN	50		AIR	WATER PUMP
10 FT								6 IN	2 IN
HAULAGE SYSTEM		PERSONNEL		SUPPORT SYSTEM		SET-SIZE-SHAPE		SHOTCRETE	
MUCK	RAIL	R-IL	SUPPLY	RAIL	BOLT, TYPE SIZE	ROOF PLATE			
44CF	ROCKERCARS				6 FT X 5/8 IN	3FT-4FT-6FT			
4-6T	MOTORS				21 BOLTS/5 FT	6 PLATES/5FT			
30 LB	RAIL				SPAN				
18 IN	GAGE								

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
MAKE	WT	HEAD, CENTER	HEAD	CENTER
MODEL	INTERIOR	KFTLB	KFTLB	KFTLB
	GAGE	KFTLB	KFTLB	KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDOANCE	THRUST/50 FT
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE	ROUND	EXPLOSIVES,	BLASTING	MUCKING	GUIDOANCE
JUN-80	NO. MOLES	POWDER FACTOR	ELECTRICAL	EIMCO	LASER
3	42-50	8.2 LB/CY	IGNITER CORD	21	
MACHINES	DEPTH	TOTAL LBS	NO. 6 CAPS, FUSE		
3IN DIA	5.5 FT	150			
ORIFER	DIAM.	PRIMERS, 25 LB			
	1 3/8 IN	ANOGEL NO. 4			
	CUT, V	TRIM CARBAMITE			
		INTERIOR CARBAMITE			
		CUT CARBAMITE			
		LIFTERS CARBAMITE			

FEED LENGTH 7FT



## KEY

32A  
TUNNEL DATA

TUNNEL	VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	MP	GPM
9 FT	1 RECT	0.0	9K	X	24 IN	50	NONE	AIR
0 FT								WATER PUMP
								6 IN 2 IN

HAULAGE SYSTEM	PERSONNEL		SUPPLY		SUPPORT SYSTEM		SET, SIZE, SHAPE	
MUCK	RAIL	RAIL	BOLT, TYPE, SIZE	HOOF PLATE	SHOTCRETE			
44CF	WOCKER	RAIL	6 FT X 5/8 IN	3.4 1/2, 6 FT				
CUMP	4-6T MOTOR		21 BOLTS/5 FT	7 PLATES 1				
30LB	RAIL		SPAN					
18 IN	GAGE							

## MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES		RPM		TORQUE, MAX, D/PERATE		THRUST, MAX, OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD, CENTER	HEAD	CENTER
						KFTLB	KFTLB	KFTLB
						KFTLB	KFTLB	KFTLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/50 FT
KLB				KLB

## CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES		EXPLOSIVES,		BLASTING		GUIDANCE	
JUMP	2 ROOM	50	POWDER FACTOR 6.7		ELECTRICAL		MUCKING	
MACHINES	3 IN DIA	DEPTH 5.5 FT	TOTAL LBS 122		IGNITER CORD		EIMCD	
DRIFTER		DIAM. 1 3/8 IN	PRIMERS, AMOGEL		FUSE NO. 6 CAPS		21	
FEED LENGTH	6 FT	CUT, V	INTERIOR AMOGEL DR CARBANITE					
			CUT					
			LIFTERS					

MSU-2 CURRENT: 09/01/72

# KEY IDENTIFICATION 33 LAWRENCE

## ROCK PROPERTIES

SEDIMENTARY: LIMESTONE LIGHT  
TO MEDIUM GRAY FINE GRAINED,  
SOME CHERT NOODULES, TRACES TO  
OCCASIONAL CLAY PARTINGS

DRY  
WT  
PCF

COMPR  
KPSI

RQD  
PCT  
EST

SHORE  
MOH

MARONNESS  
SCHMIDT

SAMPLE NO  
LAW-2

NA

NA

46

100

19

16%

## MUCK DATA DRY UNIT WT PCF

MOISTURE  
PCT

PER CENT BY WEIGHT BETWEEN SCREENS.....  
IN-SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4

ND200

ND100

ND50

ND30

ND16

ND8

NO4

NO200

PCT (-)

ND200

92

7.2

0.0

0.0

3.0

25.0

18.0

22.1

9.4

6.5

3.5

2.0

1.8

0.8

7.9

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PAI PI P: PI I I AI A I

## POT VOL CHANGE (-)0.065 IN.SIZE

LIQUID LIMIT PCT  
PLASTIC LIMIT PCT  
SHRINKAGE LIMIT PCT  
PLASTICITY INDEX  
FLOW INDEX  
TOUGHNESS INDEX

0

12.5

12.3

9.6

0.2

4.0

0.05

## (-)0.75 IN.SIZE SPECIFIC GRAVITY

ANGLE/REPOSE  
1 IN DROP  
DEGREES AT  
5.4 PCT MOIST

ANGLE/SLIDE  
STEEL PLATE  
DEGREES AT  
5.4 PCT MOIST

APPARENT  
COHESION  
PSF AT  
PCT MOIST

BULK  
DENSITY  
PCF AT  
PCT MOIST

SIZE(-)2.0 IN.  
ANGLE INTER  
FRICTION  
DEGREES AT  
7 PCT MOIST

2.83

39

38

31

NA

NA

30

LAW-2

CURRENT: 1 SEPT. 1972

## KEY

33A  
TUNNEL DATA

## TUNNEL

SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	WATER INFLOW	UTILITY LINES	POWER SYSTEM
13FT.	ROUND	+0.25PCT	21K		X	28IN		GPM	AIR WATER PUMP	PRIMARY SECONDARY
8IN								40-12	6IN 2IN 6IN	4160V 480V

## HAULAGE SYSTEM

MUCK RAIL	PERSONNEL RAIL	SUPPLY RAIL	BOLT, TYPE SIZE	ROOF PLATE	SUPPORT SYSTEM	SET, SIZE, SHAPE	SHOTCRETE
			NONE				

## MACHINE EXCAVATION

MACHINE	MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
ALKIRK	MAROROCK	400	400	I LAWRENCE TCB	11 LAWRENCE TCB	5 LAWRENCE TCB	9 30	HEAD CENTER	CENTER
			TONS	24IN TRICONE	15IN DISC	15IN ROLLER		KFTLB KFTLB206	KFTLB KFTLB
					11-TCB 15IN				KLB 614

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKETS FROM FACE, 24IN CONVEYOR TO REAR	ELECTRO-HYDRAULIC 600HP HEAD 150 CENTER	LASER	KLB 4.28

## CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES	EXPLOSIVES, POWDER FACTON	GUIDANCE
JUMBO MACHINES	DEPTH DIA. CUT.	TOTAL LBS PRIMERS, TRIM INTERIOR CUT	
FEED LENGTH		LIFTERS	

BLASTING	MUCKING	GUIDANCE
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LAW-2

CURRENT: 09/01/77

# KEY IDENTIFICATION % LAWRENCE

## ROCK PROPERTIES

SEDIMENTARY: LIMESTONE LIGHT  
TO MEDIUM GRAY, FINE GRAINED.  
SOME CHERT NOODULES. TRACES TO  
OCCASIONAL CLAY PARTINGS.

SAMPLE NO  
LAW-3

.....HARDNESS.....  
SHORE MOH SCHMIDT

RQD

COMPR  
STRNTH  
KPSI

DRY  
WT  
PCF

160

19

100

46

NA

NA

## MUCK DATA

DRY UNIT MOISTURE PCT(%) 6 PCT(%) 16 PER CCNT BY WEIGHT BETWEEN SCREENS..... PCT (-) PCT (-)  
WT PCF IN-SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 NO200

93 5.5 0.0 0.0 4.3 25.9 19.6 20.2 7.4 5.0 3.5 1.8 1.3 1.1 9.9

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PAI PAI PI PAI I PAI I I I I I

POT VOL CHANGE  
(-)10.065 IN-SIZE

LIQUID  
LIMITS  
PCT

11.8

10.6

10.0

1.2

2.9

0.41

TOUGHNESS  
INDEX

(-)0.75 IN-SIZE  
SPECIFIC  
GRAVITY

2.80

41

40

38

NA

NA

32

SIZE(-)2.0  
ANGLE INTER  
FRICTION  
DEGREES AT  
7 PCT MOIST

LAW-3

CURRENT: 1 SEPT. 1972

## KEY

34A  
TUNNEL DATA

TUNNEL	VENTILATION		WATER INFLOW		UTILITY LINES	POWER SYSTEM
SIZE 13FT 8IN	GRADE +0.25PCT	CFM 20K	PRESS EXHST X	SIZE 28IN	HP	PRIMARY 4160V SECONDARY 480V
SHAPE ROUND	PERSONNEL RAIL		SUPPORT SYSTEM		SET SIZE SHAPE	SHOTCRETE
HAULAGE SYSTEM	SUPPLY RAIL		DOLT TYPE SIZE		ROOF PLATE	
MUCK RAIL			NONE			

## MACHINE EXCAVATION

MACHINE	CUTTERS MAKE TYPE DIAM CUTTING EDGES				RPM	TORQUE MAX/OPERATE	THRUST MAX/OPERATE
MAKE ALKIRK	MODEL HARDROCK	WT 400 TONS	CENTER 1 LAWRENCE TCB 24IN TRICONE	INTERIOR 11 LAWRENCE TCB 15IN OISC, 11 TCB 15IN ROLLER	HEAD CENTER 9 30	HEAD KFTLB KFTLB206	CENTER KFTLB KFTLB
							KLB KLB 614

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDOANCE	THRUST/SQ FT
KLB	RUCKETS FROM FACE, 24IN CONVEYOR TO REAR	ELECTRO-HYDRAULIC 600HP HEAD 150 CENTER	LASER	KLB 4.28

## CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES	ROUND NO. HOLES DEPTH DIAM. CUT	EXPLOSIVES POWDER FACTOR TOTAL LBS PRIMERS TRIM INTERIOR CUT LIFTERS	BLASTING	MUCKING	GUIDOANCE
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## FEED LENGTH

LAN-3 CURRENT: 09/01/72

KEY IDENTIFICATION  
35 LAWRENCE

## POCK PROPERTIES

**POCK PROPERTIES  
SEDIMENTARY: LIMESTONE LIGHT  
TO MEDIUM GRAY FINE GRAINED,  
SOME CHERT NODULES. TRACES TO  
OCCASIONAL CLAY PARTINGS.**

COMPR	ROD
STRNTH	PCT
KPSI	EST
19	100

.....HARDNESS.....  
SHORE MOH SCHMIDT

.....HARDNESS.....  
SHORE MOH SCHMIDT

MUCK DATA  
 DLY UNIT  
 WT PCF

PCT (°)6		PER CENT BY WEIGHT BETWEEN SCREENS.....		PCT (-)								
IN-57ZE	6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200

	7.9	0.0	0.0	5.0	18.3	16.3	17.0	7.3	5.1	3.4	5.5	3.8	2.0	14.3
100	7.9	0.0	0.0	5.0	18.3	16.3	17.0	7.3	5.1	3.4	5.5	3.8	2.0	14.3

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES    A=ANGULAR    S=SUBANGULAR    R=ROUNDED    P=PLATY    C=CUBIC    I=IRREGULAR    E=ELONGATED    SP=SPHEROID

POT VOL CHANGE  
(-)0.056 IN.SIZE

.....ATTBERG LIMITS.....SIZE(1/4) 0.05IN.....		.....FLOX.....		.....TOUGHNESS.....	
LIQUID	PLASTIC	SHRINKAGE	PLASTICITY	INDEX	INDEX
LIMITS	LIMIT	LIMIT	LIMIT	INDEX	INDEX
PCT	PCT	PCT	PCT	PCT	PCT

Time (min)	0	20.2	20.0	13.5	0.2	4.7	0.05
0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0
130	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0
160	0	0	0	0	0	0	0
170	0	0	0	0	0	0	0
180	0	0	0	0	0	0	0
190	0	0	0	0	0	0	0
200	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0
220	0	0	0	0	0	0	0
230	0	0	0	0	0	0	0
240	0	0	0	0	0	0	0
250	0	0	0	0	0	0	0
260	0	0	0	0	0	0	0
270	0	0	0	0	0	0	0
280	0	0	0	0	0	0	0
290	0	0	0	0	0	0	0
300	0	0	0	0	0	0	0
310	0	0	0	0	0	0	0
320	0	0	0	0	0	0	0
330	0	0	0	0	0	0	0
340	0	0	0	0	0	0	0
350	0	0	0	0	0	0	0
360	0	0	0	0	0	0	0
370	0	0	0	0	0	0	0
380	0	0	0	0	0	0	0
390	0	0	0	0	0	0	0
400	0	0	0	0	0	0	0
410	0	0	0	0	0	0	0
420	0	0	0	0	0	0	0
430	0	0	0	0	0	0	0
440	0	0	0	0	0	0	0
450	0	0	0	0	0	0	0
460	0	0	0	0	0	0	0
470	0	0	0	0	0	0	0
480	0	0	0	0	0	0	0
490	0	0	0	0	0	0	0
500	0	0	0	0	0	0	0
510	0	0	0	0	0	0	0
520	0	0	0	0	0	0	0
530	0	0	0	0	0	0	0
540	0	0	0	0	0	0	0
550	0	0	0	0	0	0	0
560	0	0	0	0	0	0	0
570	0	0	0	0	0	0	0
580	0	0	0	0	0	0	0
590	0	0	0	0	0	0	0
600	0	0	0	0	0	0	0
610	0	0	0	0	0		

(-)0.75 IN. SIZE  
SPECIF  
GRAVITY

*.....MATERIAL SIZE (-2.0	ANGLE/REPOSE	ANGLE/REPOSE	ANGLE/SLIDE
1 IN DROP	10 IN DROP	10 IN DROP	STEEL PLATE
DEGREES AT	DEGREES AT	DEGREES AT	DEGREES AT
8.9 PCT MOIST	8.9 PCT MOIST	8.9 PCT MOIST	8.9 PCT MOIST

APPARENT COHESION PSF AT	BULK DENSITY PCF AT	PCT MOIST
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SIZE(-)2.0 IN.  
ANGLE INTER  
FRICTION  
DEGREES AT  
8.8 PCT MOIST

2.73

42

35

37

44

4

28

LAW-4

**CURRENT: 1 SEPT. 1972**



## KEY

35A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM					
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR	WATER	PUMP	PRIMARY	SECONDARY
13FT	ROUND	+0.25PCT	21K		X	28IN		40-120	6IN	2IN	6IN	4160V	480V
8IN													
HAULAGE SYSTEM		PERSONNEL		SUPPLY		SUPPORT SYSTEM		SET-SIZE-SHAPE		SHOTCRETE			
RAIL		RAIL		RAIL		NONE							

## MACHINE EXCAVATION

MACHINE	CUTTERS-MAKE-TYPE-DIAM-CUTTING EDGES		RPM	TORQUE-MAX/OPERATE		THRUST-MAX/OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD-CENTER	CENTER
ALIRK	HARDROCK	400	1 LAWRENCE TCS	13 LAWRENCE TCS	5 LAWRENCE	9 30	
		TONS	24IN TRICONE	15IN DISC, 11	15IN ROLLER	KFTLB	KFTLB
				16 15IN ROLLER		KFTLB206	KFTLB
							KLB 540

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKETS FROM	ELECTRO-	LASER	KLB 3.76
	FACE, 24IN	HYDRAULIC		
	CONVEYOR TO	600HP		
	REAR	150 HEAD		

## CONVENTIONAL EXCAVATION

MACHINE	ROUND	EXPLOSIVES	BLASTING	MUCKING	GUIDANCE
JUMBO	NO. HOLES	POWDER FACTOR			
MACHINES	DEPTH	TOTAL LBS			
	DIAM.	PRIMERS			
	CUT.	TRIM			
		INTERIOR			
		CUT			
		LIFTERS			

## FEED LENGTH

LAN-4      CURRENT: 09/01/72



## KEY

36A  
TUNNEL DATA

TUNNEL	VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	GRADE	CFM	PRESS	EXHIST	SIZE	HP	GPM	AIR WATER PUMP
11FT	+0.2PCT	4K		X	18IN	25	5.	6IN 11N 6IN
2IN								
HAULAGE SYSTEM	PERSONNEL		SUPPLY		SUPPORT SYSTEM		SET, SIZE, SHAPE	
RAIL, 24IN GAGE	RAIL				BOLT, TYPE	SIZE	ROOF PLATE	4IN H RING SE/S IN
5TON MOTORS							OCCASIONAL	FAULT ZONES
							PINNED STEEL	
							LAGGING	
								SHOTCRETE

## MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES		RPM		TORQUE, MAX, OPERATE		THRUST, MAX, OPERATE	
MAKE	WOOFL	WT	CENTER	INTERIOR	GAGE	HEAD	CENTER	
JARVA	11-1100	65	1 REED STEEL	22 REED STEEL	4 REED STEEL	9.3 INTEG	KFTLB	KLB 1104
		TONS	CONE, 5 DISC	TRIPLE DISC	TRIPLE DISC	KFTLB	KFTLB	KLB 596

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB 1650	BUCKET FROM	6-50HP MOTORS	LASER	KLB 6.09
	FACE, 18IN	FOR HEAD		
	CONVEYOR TO	1-40HP MOTOR		
	REAR	HYDRAULIC		

## CONVENTIONAL EXCAVATION

MACHINE	ROUND,	EXPLOSIVES,	BLASTING	MUCKING	GUIDANCE
JUMBO	NO. HOLES	POWDER FACTOR			
MACHINES	DEPTH	TOTAL LBS			
	DIAP.	PRIMERS,			
	CUT,	TRIM			
		INTERIOR			
		CUT			
		LIFTERS			

## FEED LENGTH

MIL-1 CURRENT: 09/01/72

KEY IDENTIFICATION  
37 MILWAUKEE  
SAMPLE NO  
MIL-2

ROCK PROPERTIES  
SEDIMENTARY: LIMESTONE, GRAY.  
FINE GRAINED. HORIZONTAL JOINT  
SPACING 6 IN. TO 1 FOOT.

DRY WT PCF 166  
COMPR STRNTH KPSI 36  
RQD PCT EST 85  
SHORE MOH NA  
HARDNESS SCHMIDT NA

MUCK DATA  
DRY UNIT WT PCF

MOISTURE PCT (+) 6.1  
IN-SIZE 0.0  
PER CENT BY WEIGHT BETWEEN SCREENS.....  
6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200  
PCT (-) NO200 8.6

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PE PI PI PI PI PR S S S

POT VOL CHANGE  
(-10.056 IN-SIZE

LIQUID LIMITS PCT 20.10  
PLASTIC LIMIT PCT 16.68  
SHRINKAGE LIMIT PCT 16.37  
ATTERBERG LIMITS..SIZE(-) 0.075IN..  
PLASTICITY INDEX 3.42  
FLOW INDEX 6.10  
TOUGHNESS INDEX 0.56

(-10.75 IN-SIZE  
SPECIF GRAVITY

ANGLE/REPOSE 10 IN OROP 5.8 PCT MOIST  
ANGLE/REPOSE 10 IN URUP 5.8 PCT MOIST  
ANGLE/SLIDE STEEL PLATE DEGREES AT 5.8 PCT MOIST  
APPEARANT COHESION PSF AT 5.0 PCT MOIST  
BULK DENSITY PCF AT 5.0 PCT MOIST  
SIZE(-) 12.0 IN. ANGLE INTER FRICTION DEGREES AT 5.0 PCT MOIST

2.93

32

30

30

110

90

33

MIL-2

CURRENT: 1 SEPT. 1972

## KEY

37A  
TUNNEL DATA

TUNNEL	VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM						
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR	WATER	PUMP	PRIMARY	SECONDARY
11FT	ROUND	+0.25PCT	4K		X	18IN	25	10	6IN	1IN	6IN	4680V	440V
2IN													
HAULAGE SYSTEM	PERSONNEL		SUPPLY		SUPPORT SYSTEM		SET, SIZE, SHAPE		4IN H RING SETS IN		SHOTCRETE		
MUCK	RAIL, 24IN GAGE	RAIL											
STON MOTORS													

## MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES				RPM		TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD	CENTER	HEAD	CENTER	
JARVA	11-1100	65	1 REED STEEL	24 REED STEEL	4 REED STEEL	9.3	INTEG	KFTLB 170	KFTLB	KLB 1104
		10NS	CONE, 5 DISC	TRIPLE DISC	TRIPLE DISC			KFTLB	KFTLB	KLB 596

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THKUST/SQ FT
KLB 1650	BUCKET FROM	6-50HP MOTORS	LASER	KLB 6.09
	FACE, 18IN	FOR HEAD,		
	CONVEYOR TO	1-40HP MOTOR		
	REAR	HYDRAULICS		

## CONVENTIONAL EXCAVATION

MACHINE	ROUND,	EXPLOSIVES,	BLASTING	MUCKING	GUIDANCE
JUMBO	NO. HOLES	POWDER FACTOR			
MACHINES	DEPTH	TOTAL LBS			
	DIAM.	PRIMERS,			
	CUT,	TRIM			
		INTERIOR			
		CUT			
		LIFTERS			

## FEED LENGTH

MIL-2 CURRENT: 09/01/72

KEY IDENTIFICATION  
 38 WILWAUKEE  
 SAMPLE NO  
 WIL-3

ROCK PROPERTIES  
 SEDIMENTARY: LIMESTONE  
 FINE GRAINED. GREY

DRY WT  
 164

COMPR STRNTH  
 KPSI  
 24

ROD PCT  
 81

SHORE  
 81

MARONNESS  
 SCHMIDT

MUCK DATA  
 DRY UNIT  
 WT PCF

MOISTURE PCT(%)  
 IN-SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NOS0 NO100 NO200

79 5.1 0 0 0 25.4 32.7 17.4 4.3 3.1 2.0 1.2 0.6 0.5 12.8

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC L=IRREGULAR E=ELONGATED SP=SPHEROID

PE PI PI PI PI PA S S S

POT VOL CHANGE  
 (-)10.056 IN-SIZE

0 15.20 14.40 12.96 0.80 3.50 0.22

ATTERBERG LIMITS..SIZE(-) 0.056IN..  
 LIQUID LIMIT PCT  
 PLASTIC LIMIT PCT  
 SHRINKAGE LIMIT PCT  
 PLASTICITY INDEX  
 FLOW INDEX  
 TOUGHNESS INDEX

(-)10.75 IN-SIZE  
 SPECIF GRAVITY

2.78 36 32 60 95 36

MATERIAL SIZE(-)2.0 IN..  
 ANGLE/REPOSE 10 IN DROP DEGREES AT 2.5 PCT MOIST  
 ANGLE/SLIDE STEEL PLATE DEGREES AT 2.5 PCT MOIST  
 APPARENT COHESION PSF AT 2.3 PCT MOIST 0.0 PCT MOIST 2.3 PCT MOIST  
 BULK DENSITY PCF AT 2.3 PCT MOIST

CURRENT: 1 SEPT. 1972

MIL-3

38A  
TUNNEL DATA

## SUPPORT SYSTEM

## Machine Fatigue

MACHINE	MODEL	WT	CUTTERS, MAKE, TYPE, U/I AM, CUTTING EDGES	RPM	TORQUE, MAX/OPE RATE	THRUST, MAX/OPE RATE
MAKE JANVA	11-1108	65	CENTER 1 REED QK-1	INTERIOR 22 REED 2K3	HEAD-CENTER 9.3	CENTER
					KFTLB	KFTLB KLB
					KFTLB119	KFTLB KLB 639

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKETS TO BELT	6-50HP MOTORS DRIVE HEAD	LASER	KLB

## CONVENTIONAL EXCAVATION

MACHINE	ROUND.	EXPLOSIVES.	BLASTING	MUCKING	GUIDANCE
JUMBO	NO. HOLES	POWDER FACTOR			
MACHINES	DEPTH	TOTAL LBS			
	DIAM.	PRIMERS.			
	CUT.	TRIM			
		INTERIOR			
		CUT			
		LIFTEPS			
FEED LENGTH					

KEY IDENTIFICATION 39 MT GREEN  
 ROCK PROPERTIES  
 SEDIMENTARY: LIMESTONE  
 FINE GRAINED, LIGHT  
 GREY  
 SAMPLE NO  
 EVG-1

MOISTURE PCT 3.8 0 0 3.2 26.6 22.1 21.5 4.3 3.7 3.3 2.0 2.2 2.4 8.7  
 DRY UNIT WT PCF 168 26 100  
 COMPR STRNTH KPSI  
 RQD PCT  
 HARDNESS  
 SHORE MOH SCHMIDT

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

POT VOL CHANGE (-10.05% IN SIZE)  
 LIQUID LIMITS PCT 15.10  
 PLASTIC LIMIT PCT 13.69  
 SHrinkage LIMIT PCT 11.57  
 ATTERBERG LIMITS (-) 0.056 IN.  
 PLASTICITY INDEX PCT 1.41  
 FLOW INDEX 3.0  
 TOUGHNESS INDEX 0.47  
 SIZE (-) 2.0 IN.  
 ANGLE INTER FRICTION DEGREES AT 3.0 PCT MOIST  
 BULK DENSITY PCF AT 3.0 PCT MOIST  
 APPARENT COMESION PSF AT 3.0 PCT MOIST  
 MATERIAL SIZE (-) 2.0 IN.  
 ANGLE/REPOSE 10.1 IN DROP DEGREES AT 3.1 PCT MOIST  
 ANGLE/SLIDE STEEL PLATE DEGREES AT 3.1 PCT MOIST

2.81 37 31 70 104 42  
 CURRENT: 1 SEPT. 1972  
 EVG-1



KEY

39A  
TUNNEL DATA

TUNNEL

SIZE 10 FT  
SHAPE ROUND  
4 IN

VENTILATION

CFM 18  
PRESS EXHST X  
SIZE 30 IN 90  
HP 400

WATER INFLOW

GPM 400

UTILITY LINES

AIR WATER PUMP  
3 IN

POWER SYSTEM

PRIMARY 7200  
SECONDARY 480

HAULAGE SYSTEM

MUCK PAIL  
4 CY CARS  
ST MOTOR  
24 IN GAGE  
54 LB RAIL

PERSONNEL  
RAIL

SUPPLY  
RAIL

SUPPORT SYSTEM

SOLI TYPE SIZE ROOF PLATE  
NONE

SET SIZE SHAPE

SHOTCRETE

MACHINE EXCAVATION

MACHINE

MAKE ROBBINS  
MODEL 105-144  
WT 75 TONS

CUTTERS MAKE TYPE DIAM CUTTING EDGES

CENTER 3 ROBBINS  
11 IN DIA  
DISC  
INTERIOR 2 ROBBINS  
12 IN DIA  
DISC  
GAGE 6 ROBBINS  
12 IN DIA  
DISC

RPM

HEAD CENTER

TORQUE MAX/OPERATE

HEAD KFTLB  
KFTLB280  
CENTER KFTLB  
KFTLB

THRUST MAX/OPERATE

KLB 230  
KLB 230

ANCHOR PRESS

MUCK SYSTEM  
HUCKET  
TO BELT

POWER SYSTEM

4-100 HP  
MOTORS ORIVE  
HEAD

GUIDANCE

LASER  
KLB

THRUST/SQ FT

KLB

CONVENTIONAL EXCAVATION

MACHINE  
JUNRO  
MACHINES

ROUND  
NO. HOLES  
DEPTH  
DIAM.  
CUT

FEED LENGTH

EXPLOSIVES  
POWDER FACTOR  
TOTAL LBS  
PRIMERS  
TRIM  
INTERIOR  
CUT  
LITERS

BLASTING

MUCKING

GUIDANCE

EVG-1

CURRENT: 04/21/72

KEY IDENTIFICATION

40. MT GREEN  
SEDIMENTARY: LIMESTONE  
FINE GRAINED, LIGHT  
GREY

SAMPLE NO  
EVG-2

ROCK PROPERTIES  
SEDIMENTARY: LIMESTONE  
FINE GRAINED, LIGHT  
GREY

DRY  
WT  
PCF

COMPR  
STRATH  
KPSI

SHORE

MOH

SCHMIDT

NA NA 100

MUCK DATA

DRY UNIT MOISTURE PCT(=16 PER CENT BY WEIGHT BETWEEN SCREENS..... PCT (-)  
WT PCF IN-SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 NO200

94 2.5 0 0 2.2 24.2 26.7 17.8 4.8 3.0 3.0 2.3 3.4 2.9 9.5

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

POT VOL CHANGE  
(-)

LIQUID LIMIT PCT  
PLASTIC LIMIT PCT  
SHRINKAGE LIMIT PCT  
ATTERBERG LIMITS..SIZE(-)  
IN-SIZE  
PLASTICITY INDEX PCT  
FLOW INDEX  
TOUGHNESS INDEX

IN-SIZE  
ANGLE/REPOSE  
1 IN DROP  
DEGREES AT  
PCT MOIST

MATERIAL SIZE(-)  
ANGLE/REPOSE  
10 IN DROP  
DEGREES AT  
PCT MOIST

APPARENT COMESTION  
PSF AT  
PCT MOIST

SIZE(-)  
ANGLE INTER  
FRICTION  
DEGREES AT  
PCT MOIST

EVG-2

CURRENT: 1 SEPT. 1972

KEY

40A  
TUNNEL DATA

TUNNEL

SIZE 10 FT  
SHAPE ROUND  
4 IN

VENTILATION

CFM 18  
PRESS EXHST X  
SIZE 30 IN 90

WATER INFLOW

GPM 400

UTILITY LINES

AIR WATER PUMP  
3IN

POWER SYSTEM

PRIMARY 7500  
SECONDARY 400

HAULAGE SYSTEM

MUCK RAIL  
4CY CARS  
5T MOTOR  
24 IN GAGE  
54 LB RAIL

PERSONNEL

RAIL

SUPPORT SYSTEM

BOLT TYPE SIZE ROOF PLATE  
NONE

SET SIZE & GAPE

SHOOTCRETE

MACHINE EXCAVATION

MACHINE

MAKE ROBBINS  
MODEL 105-144  
WT 75 TONS

CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES

CENTER 3 ROBBINS  
INTERIOR 21 ROBBINS  
GAGE 2 ROBBINS  
11 IN DIA  
12 IN DIA  
DISC  
DISC

RPM

HEAD CENTER  
8  
MFTLB MFTLB  
MFTLB MFTLB

TORQUE, MAX/OPERATE

HEAD CENTER  
MFTLB MFTLB  
MFTLB MFTLB

THROST, MAX/OPERATE

HEAD CENTER  
MFTLB MFTLB  
MFTLB MFTLB

ANCHOR PRESS

MUCK SYSTEM  
BUCKET TO BELT

POWER SYSTEM

4-100 HP  
MOTORS DRIVE  
HEAD

GUIDANCE

LASER

THROST/SQ FT

KLH

CONVENTIONAL EXCAVATION

MACHINE

JUNRO  
MACHINES

ROUND  
NO. HOLES  
DEPTH  
DIAM.  
CUT

EXPLOSIVES  
POWDER FACTOR  
TOTAL LBS  
PRIMERS  
TRIM

INTERIOR  
CUT  
LIFTERS

FEED LENGTH

BLASTING

MUCK, NO

GUIDANCE

EVB-2

CURRENT: 06/11/77

KEY	IDENTIFICATION	SAMPLE NO
41	LAYOUT	LAY-1

ROCK PROPERTIES  
SEDIMENTARY: SAND  
GRAINED, LIGHT B  
MASSIVE. POROUS.  
CEMENTED.

ROD	.....HARDNESS.....		
PCT	SHORE	MDH	SCHMIDT
EST			
84	NA	NA	NA

MUCK DATA		PER CENT BY WEIGHT BETWEEN SCREENS.....*		PCT (-)	
MOISTURE	PCT#16	2IN.	3IN.	4IN.	5IN.
30% UNIT	IN-SIZE	11N.	12IN.	ND16	ND30
WT PCF				ND50	ND100
				ND200	ND200

[illegible]

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES    A=ANGULAR    S=SUBANGULAR    R=ROUNDED    P=PLATY    C=CUBIC    I=IRREGULAR    E=ELONGATED    SP=SPHEROID

19

POT VOL CHANGE (-10.056 IN.SIZE	.....ATTENBERG LIMITS.....SIZE(-) 0.056IN.....		.....FLOW INDEX		.....TOUGHNESS INDEX	
	LIQUID LIMITS	PLASTIC LIMIT	SHRINKAGE LIMIT	PLASTICITY INDEX	FLOW INDEX	TOUGHNESS INDEX
	PCT	PCT	PCT	PCT		
	21.20	17.06	15.17	3.14	6.00	0.52

(-)10.75 IN. SIZE		*.....MATERIAL SIZE(-)2.0		IN.....*		SIZE(-)2.0	
SPECIFIC GRAVITY	ANGLE/REPOSE 1 IN DROP DEGREES AT 3.6 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 3.6 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 3.6 PCT MOIST	APPARENT COMB PSF AT 3.6 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	ANGLE INTER FRICTION DEGREES AT 3.6 PCT MOIST	IN.

	37	35	27	210	97.6	97.6	38
2.66							

LAY-1 CURRENT: 1 SEPT. 1972

KEY

1A  
TUNNEL DATA

TUNNEL	VENTILATION				WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS EXHST	SIZE	MP	GPM	AIR	WATER	PUMP
12FT	ROUND	+0.125PCT15-17K		X	36IN	100	20-100	6IN	3.5IN	8IN
11IN										
HAULAGE SYSTEM	PERSONNEL				SUPPLY		BOLT TYPE SIZE		ROOF PLATE	
MUCK	RAIL	24IN GAGE	RAIL		RAIL		3/4IN X 7FT	13IN X 9FT		
65LB RAIL										
10TON MOTORS										
10 CY CARS										

MACHINE EXCAVATION

MACHINE	CUTTERS MAKE TYPE DIAM CUTTING EDGES				RPM	TORQUE MAX/OPERATE		THRUST MAX/OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD CENTER	HEAD	CENTER	
ROBBINS	141-27	125	1 ROBBINS	11IN	2 1/2 ROBBINS	12IN	5.2	INTEG	
		TONS	STEEL TRIPLE	STEEL DISC	STEEL DISC		KFTLB NA	KFTLB	KLB 900
			DISC				KFTLB 8498AV	KFTLB	KLB 357AV

ANCHOR PRESS	MUCK SYSTEM	GUIDANCE	THRUST/30 FT
KLB 1000	BUCKETS FROM	LASER	KLB 2.73
	FACE 30IN		
	CONVEYOR TO		
	REAR		

CONVENTIONAL EXCAVATION

MACHINE	ROUND	NO. HOLES	EXPLOSIVES	BLASTING	MUCKING	GUIDANCE
JUNBO	DEPTH	OIAM	CUT			
MACHINES	CUT		INTERIOR			
			CUT			
			LIFTERS			

FEED LENGTH

KEY IDENTIFICATION  
42 LAY

**ROCK PROPERTIES  
SEDIMENTARY: CONGLOMERATE  
WELL GRADED COBBLES TO  
PEBBLES OF QUARTZITE  
POORLY CEMENTED WITH  
REDDISH BROWN SANDSTONE**

COMPR	ROD	.....HARDNESS.....
STNTH	PCT	SHORE MOH SCHMIDT
KPSI		
NA	85	

DRY WT PCF	NA
0.00	0.00
0.01	0.01
0.02	0.02
0.03	0.03
0.04	0.04
0.05	0.05
0.06	0.06
0.07	0.07
0.08	0.08
0.09	0.09
0.10	0.10
0.11	0.11
0.12	0.12
0.13	0.13
0.14	0.14
0.15	0.15
0.16	0.16
0.17	0.17
0.18	0.18
0.19	0.19
0.20	0.20
0.21	0.21
0.22	0.22
0.23	0.23
0.24	0.24
0.25	0.25
0.26	0.26
0.27	0.27
0.28	0.28
0.29	0.29
0.30	0.30
0.31	0.31
0.32	0.32
0.33	0.33
0.34	0.34
0.35	0.35
0.36	0.36
0.37	0.37
0.38	0.38
0.39	0.39
0.40	0.40
0.41	0.41
0.42	0.42
0.43	0.43
0.44	0.44
0.45	0.45
0.46	0.46
0.47	0.47
0.48	0.48
0.49	0.49
0.50	0.50
0.51	0.51
0.52	0.52
0.53	0.53
0.54	0.54
0.55	0.55
0.56	0.56
0.57	0.57
0.58	0.58
0.59	0.59
0.60	0.60
0.61	0.61
0.62	0.62
0.63	0.63
0.64	0.64
0.65	0.65
0.66	0.66
0.67	0.67
0.68	0.68
0.69	0.69
0.70	0.70
0.71	0.71
0.72	0.72
0.73	0.73
0.74	0.74
0.75	0.75
0.76	0.76
0.77	0.77
0.78	0.78
0.79	0.79
0.80	0.80
0.81	0.81
0.82	0.82
0.83	0.83
0.84	0.84
0.85	0.85
0.86	0.86
0.87	0.87
0.88	0.88
0.89	0.89
0.90	0.90
0.91	0.91
0.92	0.92
0.93	0.93
0.94	0.94
0.95	0.95
0.96	0.96
0.97	0.97
0.98	0.98
0.99	0.99
1.00	1.00

MUCK DATA  
 DRY UNIT  
 WT PCF

MOISTURE	PCT(1)16	PER CENT BY WEIGHT BETWEEN SCREENS.....*	PCT (-)
PCT:	IN SIZE	6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO16 NO30 NO50 NO100 NO200	NO200

[illegible]

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES' A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

Q

P-A A

4

10

POT VDL CHANGE  
(-)0.056 IN.SIZE

*.....ATTERBERG LIMITS.....SIZE(-) 0.075IN.....*		FLOW		TOUGHNESS	
		INDEX		INDEX	
LIQUID	PLASTIC	PLASTICITY	FLOW	TOUGHNESS	
LIMITS	LIMIT	LIMIT	INDEX	INDEX	
PCT	PCT	PCT	PCT	PCT	

0	15.00	14.18	13.80	0.82	4.00	0.21
---	-------	-------	-------	------	------	------

-10.75 IN.SIZE \*.....  
 SPECIFIC ANGLE/REFDSE  
 GRAVITY I IN DROP  
 DEGREES AT  
 3.4 PCT MOIST

*****MATERIAL SIZE(1)-2.0		*****IN*****		*****SIZE(1)-2.0	
ANGLE/REPOSE	ANGLE/SLIDE	APPARENT	BULK	ANGLE INTER	
I IN DROP	STEEL PLATE	COMESION	DENSITY	FRICITION	
DEGREES AT	DEGREES AT	PSF AT	PCF AT	DEGREES AT	
3.4 PCT MOIST	3.4 PCT MOIST	3.0 PCT MOIST	0.0 PCT MOIST	3.0 PCT MOIST	

2.65 30

68

**LAY-2**

**CURRENT: 1 SEPT. 1972**

KEY

42A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS EXHST	SIZE	HP	AIR	WATER PUMP	PRIMARY SECONDARY
12 FT	ROUND	+0.125	15-7K	X	36 IN	100	6 IN	3.5 IN	7300 460
11 IN									

HAULAGE SYSTEM		SUPPORT SYSTEM		SHOTCRETE	
MUCK	PERSONNEL	BOLT, TYPE	SIZE	ROOF	PLATE
10 CY CAPS	RAIL				
10 MOTOR					
24 IN GAGE					
65 LB RAIL					

MACHINE EXCAVATION

MACHINE		CUTTERS, MAKE, TYPE, DIA, CUTTING EDGES		RPM		TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MAKE	MODEL	WT	INTERIOR	GAGE	6 RD	DISC	HEAD	CENTER	
ROBBINS	141-127	125 TON	23 ROBBINS	11 IN DIA	DISC		KFTLB	KFTLB	KLB 585

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/50 FT
KLB	BUCKETS TO BELT	6-100 HP MOTORS	LASER	KLB 4.47

CONVENTIONAL EXCAVATION

MACHINE	ROUND	EXPLOSIVES,	BLASTING	MUCKING	GUIDANCE
JUMBO	NO. HOLES	POWDER FACTOR			
MACHINES	DEPTH	TOTAL LBS			
	DIA.	PRIMERS,			
	CUT	TRIM			
		INTERIOR			
		CUT			
		LIFTERS			

FEED LENGTH

LAY-2 CURRENT: 09/01/72

# KEY IDENTIFICATION

43. NAVAJO

SAMPLE NO

NAV-1

# ROCK PROPERTIES

SEOLMENTARY: SILTSTONE. FINE  
GRAINED. GRAY. MORE THAN 33  
PCT QUARTZ, 30 PCT CLAY, 10  
PCT FELDSPAR, 15 PCT MICA,  
CHLORITE AND GYPSUM.

DRY

WT

PCF

142

COMPR

STRNTH

KPSI

2

RQD

PCT

EST

70

SHORE

MOH

NA

NA

HARDNESS

SCHMIDT

NA

NA

# MUCK DATA

DRY UNIT

WT PCF

86

MOISTURE

PCT

0.0

PER CENT BY WEIGHT BETWEEN SCREENS.

NO4 NO8 NO16 NO30 NO50 NO100 NO200

0.0

12.1

7.4

6.9

2.2

0.6

1.3

1.8

2.1

5.9

9.3

44.5

SCREEN ANALYSIS: UPPER LINE, DRY SCREENED (ASTM C136). AFTER WASHING (ASTM C117), LOWER LINE, SCREENED BEFORE DRYING

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PI

PI

PI

PI

AI

SI

S

S

A

A

POT VOL CHANGE

(-)0.056 IN.SIZE

1.3

LIQUID

LIMITS

PCT

36.80

PLASTIC

LIMIT

PCT

23.61

SHRINKAGE

LIMIT

PCT

21.04

PLASTICITY

INDEX

PCT

13.19

FLOW

INDEX

PCT

7.00

TOUGHNESS

INDEX

PCT

1.80

(-)0.75 IN.SIZE

ANGLE/REPOSE

1 IN DROP

DEGREES AT

7.7 PCT MOIST

3.13

ANGLE/REPOSE

10 IN DROP

DEGREES AT

7.7 PCT MOIST

ANGLE/SLIDE

STEEL PLATE

DEGREES AT

7.7 PCT MOIST

APPARENT

COMESION

PSF AT

7.5 PCT MOIST

BULK

DENSITY

PCF AT

7.5 PCT MOIST

SIZE(-)2.0 IN.

ANGLE INTER

FRICITION

DEGREES AT

7.5 PCT MOIST

30

30

30

30

340

98

36

NAV-1

CURRENT: 1 SEPT. 1972



## KEY

43A  
TUNNEL DATA

TUNNEL		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM					
SIZE	SHAPE	GHADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR	WATER	PUMP	PRIMARY	SECONDARY
20FT	ROUND	±0.05PCT	18K		X	30IN	60	1	6IN	4IN	4IN	4160V	440V
6IN													
HAULAGE SYSTEM		PERSONNEL		SUPPLY		SUPPORT SYSTEM		SET, SIZE, SHAPE		SHOTCRETE		TO PREVENT AIR	
RAIL, 24IN GAGE		RAIL		RAIL		BOLT, TYPE SIZE		ROOF PLATE		TO PREVENT AIR		SLACKING	
70LB, 16CY CARS						3/4IN X 8FT OR		5FT ON 13FT					
15TON MOTOR						10FT SET IN		16 GAGE					
						EPOXY							

## MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
MAKE	WT	INTERIOR	GAGE	HEAD, CENTER
ORESSER	200	30 ORESSER	6 ORESSER	5 INTEG
TR-205	TONS	4IN CHISEL	TC DISCS	KFTLB 879
		6 KENNA METAL	TC DISCS	KFTLB 586
		TC PICK BITS	KENNA METAL TCB	KFTLB 1583
		PICK BITS		KFTLB 431

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KL8 6616	BUCKETS FROM	4-180HP DC	LASER	KL8 1.31
	FACE, 36IN	MOTORS FOR HEAD		
	CONVEYOR TO	1-75HP MOTOR,		
	REAR	HYDRAULICS		

## CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES	EXPLOSIVES,	BLASTING	MUCKING	GUIDANCE
JUMBO	DEPTH	POWDER FACTOR			
MACHINES	DIAM.	TOTAL LBS			
	CUT.	PRIMERS,			
		TRIM			
		INTERIOR			
		CUT			
		LIFTERS			

FEED LENGTH

NAV-1

CURRENT: 09/01/72

KEY IDENTIFICATION  
44 NAVAJO

ROCK PROPERTIES  
SEDIMENTARY: SANDSTONE GRAY  
MEDIUM GRAINED, MASSIVE,  
FRIABLE AND POROUS. GRAINS  
ANGULAR TO SUBROUNDED,  
PRIMAIRILY QUARTZ, POORLY  
CEMENTED.

DRY WT PCF 117  
COMPR STRATH KPSI  
ROO PCT EST 60  
SHORE MOH SCHMIDT  
HARDNESS.....  
NA NA NA  
LESS THAN 1.

MUCK DATA  
DRY UNIT WT PCF

PCT(10) 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 PCT (-) ND200

97 9.2 0.0 0.0 0.0 0.0 1.3 2.5 2.3 11.8 23.2 12.7 10.0 7.1 29.1

SCREEN ANALYSIS: UPPER LINE, DRY SCREENED (ASTM C136), AFTER WASHING (ASTM C117), LOWER LINE, SCREENED BEFORE DRYING

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

B-87

POT VOL CHANGE  
(-10.056 IN.SIZE

LIQUID LIMITS PCT 18.20  
PLASTIC LIMIT PCT 16.91  
SHRINKAGE LIMIT PCT 16.60  
PLASTICITY INDEX PCT 1.29  
FLOW INDEX 4.50  
TOUGHNESS INDEX 0.28

(-10.75 IN.SIZE SPECIF GRAVITY

ANGLE/REPOSE 1 IN DROP 8.6 PCT MOIST  
ANGLE/REPOSE 10 IN DROP 8.6 PCT MOIST  
ANGLE/REPOSE 100 IN DROP 8.6 PCT MOIST  
ANGLE/SLIDE STEEL PLATE DEGREES AT 8.6 PCT MOIST  
APPARENT COMESTION PSF AT 8.1 PCT MOIST  
BULK DENSITY PCF AT 0.0 PCT MOIST  
ANGLE INTER FRICTION DEGREES AT 8.1 PCT MOIST

2.72 31

28

45

99

NAV-2 CURRENT: 1 SEPT. 1972

## KEY

44A  
TUNNEL DATA

## TUNNEL

SIZE 20FT  
6IN

SHAPE ROUND

GRADE +0.05PCT

CFM 18K

PRESS EXHST X

SIZE 30IN

HP 60

WATER INFLOW GPM 1

UTILITY LINES AIR 6IN WATER 4IN PUMP 4IN

POWER SYSTEM PRIMARY 4160V SECONDARY 440V

## HAULAGE SYSTEM

MUCK RAIL, 24IN GAGE RAIL, 16 CY CARS 15TON MOTOR

PERSONNEL RAIL

SUPPLY RAIL

SUPPORT SYSTEM BOLT, TYPE SIZE ROOF PLATE J/4IN X 8FT ON 10FT SET IN 16 GAGE EPOXY

SET, SIZE, SHAPE SHOTCRETE TO PREVENT AIR SLACKING

## MACHINE EXCAVATION

MACHINE MAKE ORESSER TH-205

WT 200 TONS

CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES CENTER 4IN CHISEL 6 KENAMETAL TC PICK BITS

INTERIOR 30 ORESSER STEEL DISC. 26 KENAMETAL TC PICK BITS

GAGE 6 ORESSER TC DISC

RPM 5

HEAD, CENTER 5 INTEG

TORQUE, MAX/OPERATE KFTLB 879 KFTLB 586

THRUST, MAX/OPERATE KLB 1583 KLB 123

ANCHOR PRESS MUCK SYSTEM UCKEY, FROM FACE, 36IN CONVEYOR TO REAR

POWER SYSTEM 4 -180HP DC MOTORS FOR HEAD 1-75HP MOTOR, HYDRAULICS

GUIDANCE L ASEN

THRUST/SQ FT KLB 0.37

## CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES

FEED LENGTH

ROUND, NO. HOLES DEPTH DIAM. CUT.

EXPLOSIVES, POWDER FACTOR TOTAL LBS PRIMERS, TRIM INTERIOR CUT LIFTERS

BLASTING MUCKING GUIDANCE

NAV-2

CURRENT: 09/01/72

KEY IDENTIFICATION  
45 ROCHESTER  
SAMPLE NO  
R0-1

ROCK PROPERTIES  
SEDIMENTARY: SANDSTONE  
FINE GRAINED, BROWN  
TO DARK RED, MASSIVE

DRY WT PCF NA  
COMPR STRNTH KPSI NA  
ROD PCT 60  
SHORE MOH SCHMIDT

MUCK DATA  
DRY UNIT WT PCF 4.3  
MOISTURE PCT 0  
PCT IN-SIZE 0  
PCT IN-SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200  
PCT (-) NO200 11.0

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PE PE PE PA P A A A A

POT VOL CHANGE (-) IN-SIZE  
\*.....ATTENBERG LIMITS..SIZE(-)  
LIQUID LIMIT PCT  
SHRINKAGE LIMIT PCT  
PLASTIC LIMIT PCT  
IN-SIZE  
PLASTICITY INDEX  
FLOW INDEX  
TOUGHNESS INDEX

(-) IN-SIZE \*.....MATERIAL SIZE(-)  
SPECIFIC GRAVITY  
ANGLE/REPOSE 1 IN DROP DEGREES AT PCT MOIST  
ANGLE/REPOSE 10 IN DROP DEGREES AT PCT MOIST  
ANGLE/SLIDE STEEL PLATE DEGREES AT PCT MOIST  
APPARENT COHESION PSF AT PCT MOIST  
BULK DENSITY PCF AT PCT MOIST  
SIZE(-) IN-SIZE  
ANGLE INTER FRICTION DEGREES AT PCT MOIST

RO-I CURRENT: 1 SEPT. 1972

45A  
TUNNEL DATA

## HAULAGE SYSTEM

BOLT TYPE	SIZE	ROOF PLATE
5/8"	6 FT. 8 FT X	12 FT 6 IN OK
5/8"	IN 24 IN	8 FT 4 IN X
CENTER		8 IN. 14 GAO

8 IN. 14 GAGUE

MACHINE	CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES	RPM	TORQUE,MAX/OPERATE	THRUST,MAX/OPERATE
MAKE LAMPENC	P: N1	HEAD,CENTER 11 30	HEAD CENTER	
	CENTER 1-25IN TCB	GAGE 5 TBC	KFTLB KFTLB364	KL8 KL8 492
	TRI CONE	INTERIOR 24 DISC AND 2 TCB ROLLER	KFTLB KFTLB	

RPM	HEAD-CENTER	HEAD	CENTER	TORQUE, MAX/OPERATE
11				
30				
		KFTLB	KFTLB	
		KFTLB364	KFTLB	

POWER SYSTEM	GUIDANCE	THRUST/50 FT
ELECTRO-	LASER	
HYDRAULIC		KLd
960 HP		:

**MUCK SYSTEM  
BUCKET  
TO DELT**

MACHINE JUMBO MACHINES	ROUND, NO. HOLES DEPTH DIAM. CUT,
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
14	14
15	15
16	16
17	17
18	18
19	19
20	20
21	21
22	22
23	23
24	24
25	25
26	26
27	27
28	28
29	29
30	30
31	31
32	32
33	33
34	34
35	35
36	36
37	37
38	38
39	39
40	40
41	41
42	42
43	43
44	44
45	45
46	46
47	47
48	48
49	49
50	50
51	51
52	52
53	53
54	54
55	55
56	56
57	57
58	58
59	59
60	60
61	61
62	62
63	63
64	64
65	65
66	66
67	67
68	68
69	69
70	70
71	71
72	72
73	73
74	74
75	75
76	76
77	77
78	78
79	79
80	80
81	81
82	82
83	83
84	84
85	85
86	86
87	87
88	88
89	89
90	90
91	91
92	92
93	93
94	94
95	95
96	96
97	97
98	98
99	99
100	100

EXPLOSIVES,  
POWDER FACTOR  
TOTAL LBS  
PRIMERS,  
TRIM  
INTERIOR  
CUT  
LIFTEPS

## BLASTING MUCKING GUIDANCE

## FEED LENGTH

**CURRENT: 09/01/72**

KEY IDENTIFICATION  
46. WESTERN  
NUCLEAR  
SAMPLE NO  
WNG-1

**ROCK PROPERTIES**  
SEDIMENTARY: SANDSTONE COARSE GRAINED. POORLY CONSOLIDATED. ARKOSIC. WITH MINOR LAYERS OF THIN SEAMED SILTSTONE.

DRY WT PCF	COMPR STRENGTH MPsi	RQD PCT EST	SHORE HARDNESS MON	SCHMIDT HARDNESS NA
125	30	NA	NA	NA

LESS THAN 1.

[illegible][illegible]

SCREEN ANALYSIS: UPPER LINE, DRY SCREENED (ASTM C136), AFTER WASHING (ASTM C117), LOWER LINE, SCREENED BEFORE DRYING

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES    A=ANGULAR   S=SUBANGULAR   R=ROUNDED   P=PLATY   C=CUBIC   I=IRREGULAR   E=ELONGATED   SP=SPHEROID

**AE**

5



A

•

3

4

POT VOL CHANGE  
(-10.056 IN-SIZE

•.....  
LIQUID  
LIMITS  
PCT

.....  
PLASTIC  
LIMIT  
PCT

ENERG LIMITS.  
SPRINGAGE  
L.A.T  
PCT

0.0561N.  
PLASTICITY  
INDEX  
PCT

INDEX  
FLOW  
.....

TOURMENT 53  
INDEX



**24.90**

19.97

19.44

**4.93**

7.40

3.05

**X-10.75 IN. SIZE  
SPECIFIC  
GRAVITY**

\*\*\*\*\*  
ANGLE/REPCSE  
I IN DROP  
DEGREES AT  
10.1 PCT MOIST

.....MATERIAL  
ANGLE/REPOSE  
10 IN DROP  
DEGREES AT  
10.1 PCT MOIS.

ANGLE/SLIDE  
STEEL PLATE  
DEGREES AT  
10.0 PCT MOIS

.....  
APPARENT  
COHESION  
PSF AT  
10.6 PCT M

.....  
BULK  
DENSITY  
PCF AT  
0.0 PCT MO

**Dist**

SIZE(-)2.0 IN.  
ANGLE INTER  
FRICTION  
DEGREES AT  
10.6 PCT MOIST

## 2.71

43

31

32

0

50

27

WNG-1

**CURRENT: 1 SEPT. 1972**

KEY

46A  
TUNNEL DATA

TUNNEL	VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM
10FT X	RECT	0.5PCT	5-7K	X	20-25	AIR	WATER PUMP	4IN
8FT								
HAULAGE SYSTEM	PERSONNEL		SUPPLY		SUPPORT SYSTEM		SHOTCRETE	
MUCK	RAIL	RAIL	RAIL	RAIL	RAIL	RAIL	RAIL	IN BAD
RAIL	24IN	GAGE	RAIL	RAIL	RAIL	RAIL	RAIL	GROUND
40LB	RAIL							

MACHINE EXCAVATION

MACHINE	MAKE	MODEL	WT	CUTTERS	MAKE	TYPE	DIAM	CUTTING	EDGES	RPM	HEAD	CENTER	TORQUE	MAX/OPERATE	THRUST	MAX/OPERATE
ALPINE	MINER	F6-A	11	72	KENNAMETAL	U	43	K	PICK BITS	60	KFTLB	KFTLB	KFTLB	KFTLB	KLB	KLB
			TONS	MOUNTED	ON	TWIN	RIPPER	HEADS								

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	GATHERING ARMS	440V ELECTRIC	TRANSIT	KLB
	14IN CHAIN CONV MOTORS	LASER		
	14IN BELT CONV. 50.4HP HEAD			
	TO REAR	2-20.2HP THRUST		

CONVENTIONAL EXCAVATION

MACHINE	ROUND	NO. HOLES	EXPLOSIVES	GUIDANCE
JUMBO	NO. HOLES	DEPTH	POWDER FACTOR	MUCKING
MACHINES	DIAM.	CUT	TOTAL LBS	BLASTING
			PRIMERS	
			TRIM	
			INTERIOR	
			CUT	
			LIFTERS	

FEED LENGTH

# KEY IDENTIFICATION

47 WESTERN  
NUCLEAR  
SAMPLE NO  
WNG-2

## ROCK PROPERTIES

SECONDARY: SANDSTONE COARSE  
GRAINED, POORLY CONSOLIDATED,  
ARKOSIC, WITH MINOR LAYERS  
OF THIN SEAMED SILTSTONE,  
VARYING CONCENTRATIONS OF  
CARBONIFEROUS MATERIAL  
REPLACED BY SILICA.

DRY  
WT  
PCF

COMPR  
STRNTH  
KPSI

RQD  
PCT  
EST

SHORE  
MOH

HARDNESS  
SCHMIDT

MUCK DATA  
QTY UNIT  
WT PCF

MOISTURE PCT(+)6  
IN-SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 PCT (-)

93 8.3 0.0 0.0 0.0 0.0 2.0 4.0 5.0 11.0 16.0 16.0 18.0 7.9 20.1  
0.0 8.7 5.4 7.9 7.3

SCREEN ANALYSIS: UPPER LINE. DRY SCREENED (ASTM C136). AFTER WASHING (ASTM C117). LOWER LINE. SCREENED BEFORE DRYING

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

B-93

POT VOL CHANGE  
1-10.05A IN-SIZE

LIQUID  
LIMIT  
PCT

PLASTIC  
LIMIT  
PCT

SHRINKAGE  
LIMIT  
PCT

PLASTICITY  
INDEX  
PCT

FLOW  
INDEX

TOUGHNESS  
INDEX

0

25.25

24.74

23.37

0.51

4.00

0.13

(-10.75 IN-SIZE  
SPFCIF  
GRAVITY

ANGLE/REPOSE  
I IN DPOD  
DEGREES AT  
9.0 PCT MOIST

ANGLE/2POSE  
10 IN DPOD  
DEGREES AT  
9.0 PCT MOIST

ANGLE/SLOE  
STEEL PLATE  
DEGREES AT  
9.0 PCT MOIST

APPARENT  
COMESION  
PSF AT  
9.0 PCT MOIST

BULK  
DENSITY  
PCF AT  
0.0 PCT MOIST

SIZE(-)2.0 IN.  
ANGLE INTER  
FRICTION  
DEGREES AT  
9.0 PCT MOIST

2.72

32

31

40

0

86

28

WNG-2

CURRENT: 1 SEPT. 1972



## KEY

47A  
TUNNEL DATA

TUNNEL	VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
SIZE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR
SFT X	SHAPE	S-7K	X	18IN	18IN	HP	DRY	WATER PUMP
5FT	RECT							2IN 1IN
HAULAGE SYSTEM		SUPPORT SYSTEM		ROOF PLATE		SET SIZE SHAPE		SHOTCRETE
PERSONNEL	SUPPLY	BOLI TYPE SIZE		ROOF PLATE		SET SIZE SHAPE		SHOTCRETE
RAIL	RAIL	AIR HOIST		ROOF PLATE		SET SIZE SHAPE		SHOTCRETE
42IN SCRAPER								
RAIL								

## MACHINE EXCAVATION

MACHINE	CUTTERS MAKE TYPE DIAM CUTTING EDGES		RPM	TORQUE MAX/OPERATE	THRUST MAX/OPERATE
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE
			KFTLB	KFTLB	KFTLB
			KFTLB	KFTLB	KFTLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/50 FT
KL8				KL8

## CONVENTIONAL EXCAVATION

MACHINE	ROUND	EXPLOSIVES	BLASTING	MUCKING	GUIDANCE
JUMBO	NO. HOLES 18	POWDER FACTOR 5.0LB/CT	SAFETY FUSE	SCRAPER	TRANSIT
MACHINES	DEPTH 6FT	TOTAL LBS 50. 40PCT GELEX 2	CAPS		
WOODS-AIRLEG	OIAM. 1.5IN	PRIMERS			
FEED LENGTH 6FT	CUT. BURN 5 HOLE	TRIM			
		INTERIOR			
		CUT			
		LIFTERS			
	SF/HOLE 2.5				

WNS-2

CURRENT: 09/01/72

KEY IDENTIFICATION  
48 SAN FERNANDO

SAMPLE NO  
SF-1

ROCK PROPERTIES  
SEDIMENTARY: SANDSTONE ARKOSIC  
IRREGULARLY BEDDED, LOOSELY  
CONSOLIDATED WITH LAYERS AND  
LENSES OF SILTY MUDESTONE.

DRY  
WT  
PCF  
1:3  
LESS THAN 1.

COMPR  
KPSI

ROD  
PCT  
EST

SHORE  
MOH  
SCHMIDT

HARDNESS  
NA  
NA  
NA

MUCK DATA  
DRY UNIT  
WT PCF

MOISTURE PCT(+)16  
PCT IN-SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 PCT (-) NO200

91 18.5 0.0 0.0 0.0 0.0 2.2 4.5 6.1 7.0 11.5 14.4 12.8 36.4

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED S=SPHEROID

RE

SE

AI

AI

A

POT VOL CHANGE  
(-)0.065 IN-SIZE

LIQUID LIMIT PCT 17.75  
PLASTIC LIMIT PCT 16.19  
SHRINKAGE LIMIT PCT 13.94  
ATTERBERG LIMITS..SIZE (-) 0.185IN.  
PLASTICITY INDEX PCT 1.56  
FLOW INDEX PCT 5.8  
TOUGHNESS INDEX PCT 0.27

(-)0.185IN-SIZE  
SPECIFIC GRAVITY

ANGLE/REPOSE 1 IN DROP 14.3 PCT MOIST  
ANGLE/SLIDE 10 IN DROP 12.5 PCT MOIST  
ANGLE/KEPOSE 10 IN DROP 14.3 PCT MOIST  
STEEL PLATE COMESION PSF AT PCT MOIST  
BULK DENSITY PCF AT PCT MOIST  
SIZE (-)0.185 IN. ANGLE INTER FRICTION DEGREES AT 13.0 PCT MOIST

2.86

38

33

36

NA

NA

42

SF-1

CURRENT: 1 SEPT. 1972

## KEY

48A  
TUNNEL DATA

TUNNEL	VENTILATION				WATER INFLOW		UTILITY LINES		POWER SYSTEM				
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR	WATER	PUMP	PRIMARY	SECONDARY
21FT	ROUND	+0.25PCT	20K	FACE	X	36IN		200	6IN		61N	4160V	480V

HAULAGE SYSTEM	SUPPORT SYSTEM				SHOTCRETE			
MUCK	PERSONNEL	SUPPLY	BOLT, TYPE	SIZE	ROOF	PLATE	SET, SIZE, SHAPE	
RAIL	RAIL	RAIL					CONTINUOUS PRECAST	
							CONCRETE 8IN OR	
							10IN THICK X	
							4FT - 4 SEGMENT	

## MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES				RPM	TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD, CENTER	HEAD	CENTER	
ROBBINS	2215	285	HYDRAULIC	OPERATED	RIPPER	TOOTH	KFTLB	KFTLB	KLB 7000
	RIPPER	TONS					KFTLB	KFTLB	KLB
	SHIELD								

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	RACKET TO 6FT	HYDRAULIC	LASER	KLB
	CONVEYOR TO			
	REAR			

## CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES	EXPLOSIVES, POWDER FACTOR	BLASTING	MUCKING	GUIDANCE
JUMBO	DEPTH	TOTAL LBS			
MACHINES	DIA.	PRIMERS, TRIM			
	CUT	INTERIOR CUT			
		LIFTERS			

## FEED LENGTH

SF-1

CURRENT: 09/01/72

DRY	COMPR	ROO	.....HARNES
WT	STRNTH	PCT	.....MON
PCF	KPSI	EST	SHORE SCHIOT
142	2	50	NA NA NA

	PER CENT BY WEIGHT BETWEEN SCREENS.....*					PCT (-)
	1/16	1/8	1/4	3/8	1/2	
MOISTURE						
DRY UNIT						
PCT						
WT PCF						

SCREEN ANALYSIS: UPPER LINE, DRY SCREENED (ASTM C136), AFTER WASHING (ASTM C117), LOWER LINE, SCREENED BEFORE DRYING

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND P=PLATY C=CURIC I=IRREGULAR E=ELONGATED SP=SPHEROID

.....ATTENBERG LIMITS.....SIZE(-) 0.056IN.....		FLOW		TOUGHNESS	
LIQUID	PLASTIC	SHRINKAGE	PLASTICITY	INDEX	INDEX
PCT	LIMIT	LIMIT	INDEX	PCT	
	PCT	PCT	PCT		

0.61

*.....MATERIAL		SIZE(-)I.0		IN.....*		SIZE(-)I.0		IN.	
ANGLE/REPOSE	ANGLE/REPOSE	10 IN DROP	ANGLE/SLOPE	APPARENT	BULK	ANGLE INTER	ANGLE INTER	ANGLE INTER	ANGLE INTER
OEGRES AT	OEGRES AT	OEGRES AT	STEEL PLATE	COHESION	DENSITY	FRICITION	FRICITION	FRICITION	FRICITION
15.1 PCT MOIST	15.1 PCT MOIST	15.1 PCT MOIST	OEGRES AT	PSF AT	PCF AT	DEGREES AT	DEGREES AT	DEGREES AT	DEGREES AT
15.1 PCT MOIST	15.1 PCT MOIST	15.1 PCT MOIST	15.1 PCT MOIST	PCT MOIST	PCT MOIST	15 PCT MOIST	15 PCT MOIST	15 PCT MOIST	15 PCT MOIST

27

**CURRENT:**

**1 SEPT. 1972**



# KEY IDENTIFICATION

50 KERR-MCGEE  
 DRY UNIT  
 WT PCF

SAMPLE NO  
 KH-1

## ROCK PROPERTIES

SEDIMENTARY: MUDSTONE, DARK  
 GRAY, FINE GRAINED, MASSIVE.

DRY  
 WT  
 PCF

144

11

90

NA

NA

NA

NA

## MUCK DATA

DRY UNIT  
 WT PCF

9.4

0.0

46.7

0.0

5.9

1.9

5.2

28.9

0.3

1.3

2.7

5.4

6.3

12.5

29.6

SCREEN ANALYSIS: UPPER LINE. DRY SCREENED (ASTM C136). AFTER WASHING (ASTM C117). LOWER LINE, SCREENED BEFORE DRYING

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PE

PE

PI

PI

PI

PI

PI

PI

PI

PI

PI

PI

POT VOL CHANGE  
 (-)0.056 IN-SIZE

28.30

24.97

14.12

3.33

3.60

0.92

0.92

0.92

0.92

0.92

0.92

(-)0.75 IN-SIZE  
 SPECIFIC GRAVITY

2.87

2.87

2.87

2.87

2.87

2.87

2.87

2.87

2.87

2.87

2.87

KM-1

CURRENT: 1 SEPT. 1972

## KEY

50A  
TUNNEL DATA

TUNNEL	VENTILATION				WATER INFLOW		UTILITY LINES		POWER SYSTEM		
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR	WATER	PUMP
10 FT X 9 FT	RECT	+0.5 PCT	5K	FACE	VENT	24 IN	25	DRY			
HAULAGE SYSTEM		PERSONNEL		SUPPLY		SUPPORT SYSTEM		SET, SIZE, SHAPE		SHOTCRETE	
RAIL, 36 IN GAGE		RAIL		RAIL		BOLT, TYPE		4 IN WF STEEL		SETS AT 3 FT OR 6 FT	
45 LB RAIL											

## MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES				RPM	TORQUE, MAX/OPERATE	TICK, MAX/OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD, CENTER	HEAD	CENTER
ALPINE	F6-A	11	40	43 KM	PICK PITS. MOUNTED	78	KFTLB	KFTLB
MINER		TONS	ON TWIN	RIPPER	HEADS		KFTLB	KFTLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/50 FT
KLB	GATHERING ARMS	ELECTRIC MOTORS	TRANSIT	
	14 IN FLIGHT	50.4 HP HEAD	LASER	KLU
	CONVEYOR	2-20.4 HP THRUST		

## CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES	EXPLOSIVES, POWDER FACTOR	BLASTING	MUCKING	GUIDANCE
JUMBO	DEPTH	TOTAL LBS			
MACHINES	DIA.	PRIMERS, TRIM			
	CUT.	INTERIOR CUT			
		LIFTERS			

FEED LENGTH

KM-1

CURRENT: 09/01/72

# APPENDIX C SYSTEM DATA SHEETS

<u>Identification</u>	<u>Page</u>	<u>Identification</u>	<u>Page</u>
NAST-1	C-1, C-2	5-1	C-51, C-52
NAST-2	C-3, C-4	7-2	C-53, C-54
NAST-3	C-5, C-6	11-3	C-55, C-56
NAST-4	C-7, C-8	11-4	C-57, C-58
GA-1	C-9, C-10	72-1	C-59, C-60
H-1	C-11, C-12	MSU-1	C-61, C-62
H-2	C-13, C-14	MSU-2	C-63, C-64
LK-1	C-15, C-16	LAW-2	C-65, C-66
LK-2	C-17, C-18	LAW-3	C-67, C-68
LK-5	C-19, C-20	LAW-4	C-69, C-70
LK-6	C-21, C-22	MIL-1	C-71, C-72
LK-7	C-23, C-24	MIL-2	C-73, C-74
SM-1	C-25, C-26	MIL-3	C-75, C-76
CL-1	C-27, C-28	EVG-1	C-77, C-78
LK-3	C-29, C-30	EVG-2	C-79, C-80
LK-4	C-31, C-32	LAY-1	C-81, C-82
MB-1	C-33, C-34	LAY-2	C-83, C-84
MB-3	C-35, C-36	NAV-1	C-85, C-86
ST-1	C-37, C-38	NAV-2	C-87, C-88
CR-1	C-39, C-40	RO-1	C-89, C-90
HS-1	C-41, C-42	WNG-1	C-91, C-92
NY-1	C-43, C-44	WNG-2	C-93, C-94
NY-2	C-45, C-46	SF-1	C-95, C-96
QL-1	C-47, C-48	SF-2	C-97, C-98
MB-2	C-49, C-50	KM-1	C-99, C-100



APPENDIX C  
SYSTEM DATA SHEETS

### ROCK DATA:

Lithology: Igneous, granite, gray, medium to fine grained, moderately to slightly fractured and jointed, 10 to 20% quartz, 50 to 60% feldspar, balance dark minerals.

Uniaxial Compressive Strength: 18 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 167 PCF.

Ground Water: Minor, primarily from fault zones.

Hardness: NA

### TUNNEL DATA:

Size: 9' 9" diameter. Grade: (+) 0.22%.

Ventilation System: 10 KCFM, exhaust, 22" pipe to rear of conveyor, 16" to face.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 5 to 20 gpm.

Power System: 4160/480V.

Haulage System: Muck, personnel, supplies by rail cars, 36" gage, 70# rail.

Support System: 4" ring and half sets, at 4', 3' and 2' centers in bad ground, 13" wide x 10' - 16 gage plates secured by 4-1" x 7' grouted bolts as required.

### EXCAVATION DATA:

Machine: Wirth Erkelenz, Hardrock Model. Weight: 67 tons.

Cutters: 25 Hughes Tool/Wirth Tungsten Carbide Button. Gage: 6-11 1/2" TCB roller. Interior: 15-11 1/2" TCB roller. Center: 2-11 1/2" roller and 2-11 1/2" TCB Cone.

Rotation: Head, 8 1/2 RPM

Torque: 150 K ft. # max., 110 K ft. # operating

Thrust: 290 K lbs.

Muck System: Bucket from face, 22" belt conveyor to rear.

Power System: 3-200 HP electric motor driven hydraulic pumps driving hydraulic motors.

Guidance System: Laser.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. NAST-1  
Sheet 1

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size(-) 0.065" : 0

Spec. Gravity, Material  
Size(-) 0.50" : 2.69

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.185 IN.

Liquid Limit 14.50 %

Plastic Limit 14.00 %

Shrinkage Limit 13.50 %

Plasticity Index 0.50 %

Toughness Index 0.16 %

Flow Index 3.0 %

## MATERIAL SIZE (-) 0.50 IN.

Angle/Repose 1" Drop  
@ 9.0 % Moisture, 37°

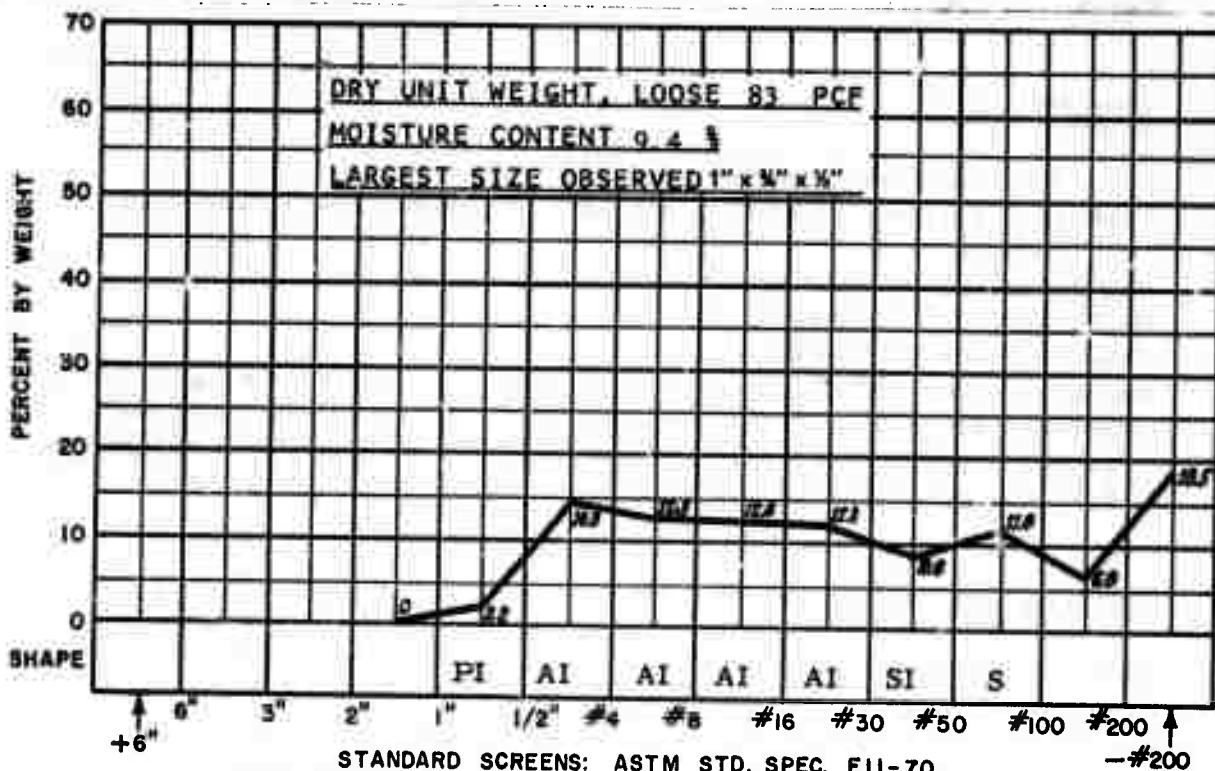
Apparent Cohesion PSF  
@ % Moisture, NA

Angle/Repose 10" Drop  
@ 9.0 % Moisture, 36°

Angle Slide Steel Plate  
@ 9.0 % Moisture, 41°

Bulk Density PCF  
@ % Moisture, NA

Angle Internal Friction  
@ 8.5 % Moisture, 42°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Igneous: Granite, moderately to slightly fractured and jointed. Medium to fine grained. High strength. RQD (Est.) 90%. DUW: 167 PCF. Ground water: Minor. Hardness: NA

System Class: TBM, Wirth Erkelenz, Hardrock, 9'9" dia. 25 Hughes Tool/ Wirth TCB roller and cone cutters. RPM: 8-1/2, 110 K ft # Torque, 290 K# Thrust. Mucking: Buckets to belt. Haulage: Rail. Support: Steel ring and half sets, roofplates and rock bolts.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. NAST-1  
Sheet 2

#### ROCK DATA:

Lithology: Igneous, granite, gray, medium to fine grained, moderately to slightly fractured and jointed, 10% to 20% quartz, 50% to 60% feldspar, balance dark minerals.

Uniaxial Compressive Strength: 18 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 167 PCF.

Ground Water: Minor, primarily from fault zones.

Hardness: NA

#### TUNNEL DATA:

Size: 9'9" diameter. Grade: (+) 0.22%.

Ventilation System: 10 KCFM, exhaust, 22" pipe to rear of conveyor, 16" to face.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 5 to 20 gpm.

Power System: 4160/480V.

Haulage System: Muck, personnel, supplies by rail cars, 36" gage 70# rail.

Support System: 4" ring and half sets, at 4', 3' and 2' centers in bad ground (approximately 650'), 13" wide x 10' - 16 gage plates secured by 4-1" x 7' grouted bolts as required, (approximately 1200').

#### EXCAVATION DATA:

Machine: Wirth Erkelenz, Hardrock Model. Weight 67 tons.

Cutters: 25 Hughes Tool/Wirth Tungsten Carbide Button. Gage: 6-11 1/2" TCB roller. Interior: 15-11 1/2" TCB roller. Center: 2-11 1/2" roller and 2-11 1/2" TCB cone.

Rotation: 8 1/2 RPM

Torque: 150 K ft # max., 100 K ft. # operating.

Thrust: 290 K lbs

Muck System: Bucket from face, 22" belt conveyor to rear.

Power System: 3-200 HP electric motor driven hydraulic pumps driving hydraulic motors and cylinders.

Guidance System: Laser.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-)0.056" : 0

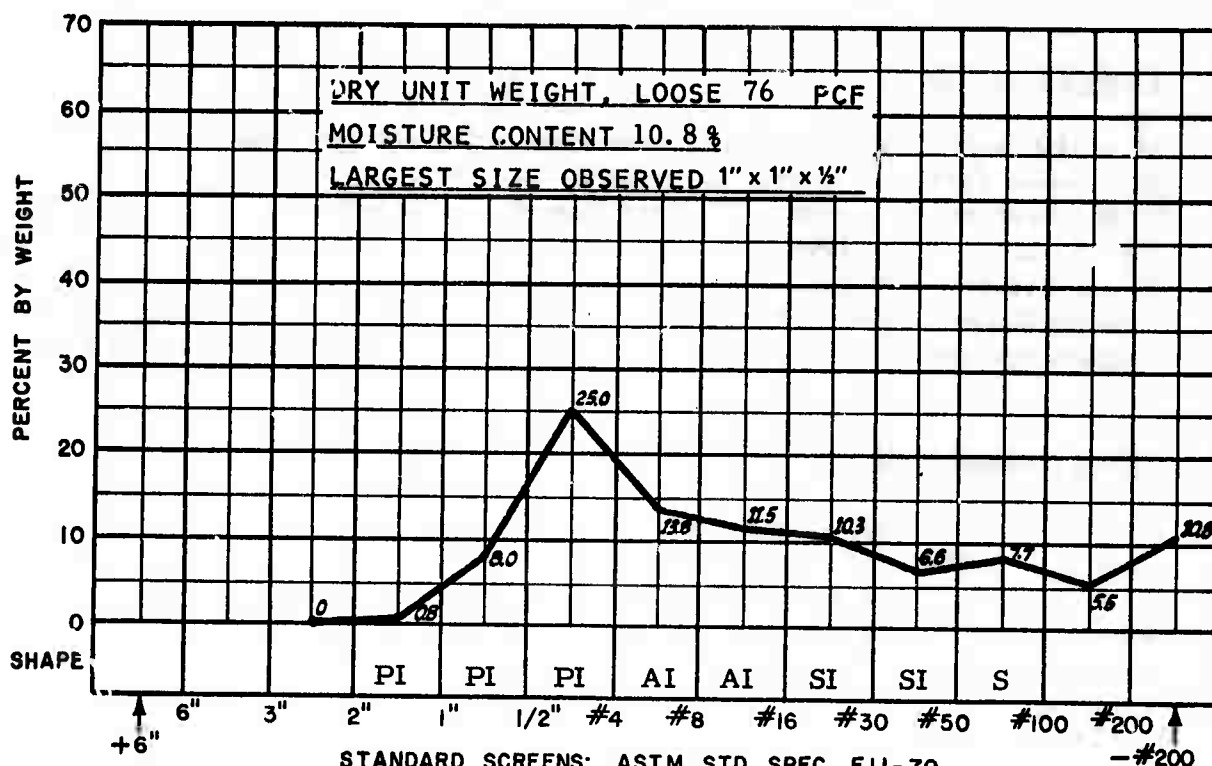
Spec. Gravity, Material  
Size (-) 0.50" : 2.66

## ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 19.5 %	Plastic Limit 18.2 %	Shrinkage Limit 17.9 %
Plasticity Index 1.3 %	Toughness Index 0.28 %	Flow Index 4.6 %

## MATERIAL SIZE (-)1.0 IN.

Angle/Repose 1" Drop @ 8.7 % Moisture, 38°	Apparent Cohesion PSF @ % Moisture, NA	Angle/Repose 10" Drop @ 8.7 % Moisture, 38°
Angle Slide Steel Plate @ 8.7 % Moisture, 49°	Bulk Density PCF @ % Moisture, NA	Angle Internal Friction @ 8.5 % Moisture, 31°



## SUMMARY

Rock Class: Igneous: Granite, medium to fine grained, moderately to slightly fractured and jointed. High strength. RQD: (Est.) 90%. DUW: 167 PCF. Ground water: Minor. Hardness: NA.

System Class: TBM, Wirth Erkelenz Hardrock. 9' 9" dia. 25 Hughes Tool/Wirth TCB roller and tricone cutters. RPM: 8-1/2, 100 K ft # Torque, 290 K# Thrust. Mucking: Buckets to belt. Haulage: Rail. Support: 4" ring and half sets, roof plates and rock bolts.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. NAST-2  
Sheet 2

**ROCK DATA:**

Lithology: Igneous, biotitic granite, fine grained, with major quartz and minor feldspar and dark mineral contents.

Uniaxial Compressive Strength: 13 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 152 PCF.

Ground Water: Minor, from fault zones.

Hardness: NA

**TUNNEL DATA:**

Size: 10' high x 16' wide x 8', alcove from 9'-9" diameter tunnel.

Ventilation System: 10 KCFM, exhaust, 22" pipe.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 5-10 GPM.

Power System: Not applicable.

Haulage System: Muck, personnel, supplies by rail cars, 36" Gage, 70# rail.

Support System: 1" x 7' grouted rock bolts and 13" x 10'-16 gage roof plates.

**EXCAVATION DATA:**

Conventional Rail Haulage System.

Drilling: 2-S53F, 4' feed, jack legs.

Drill Round: 72 holes, 1 3/4" diameter, 9' av. depth, double V-cut.

Explosives: 300# Gelox #2-60%. Powder Factor, 6.3#/CY.

Blasting: Electrical, zero and 7 regular delays.

Mucking: Diesel front end loader, 1/2 CY.

Guidance: Not applicable.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056" : 0

Spec. Gravity, Material  
Size (-) 0.75" : 2.65

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 19.50 %  
Plasticity Index 2.09 %

Plastic Limit 17.41 %  
Toughness Index 0.51 %

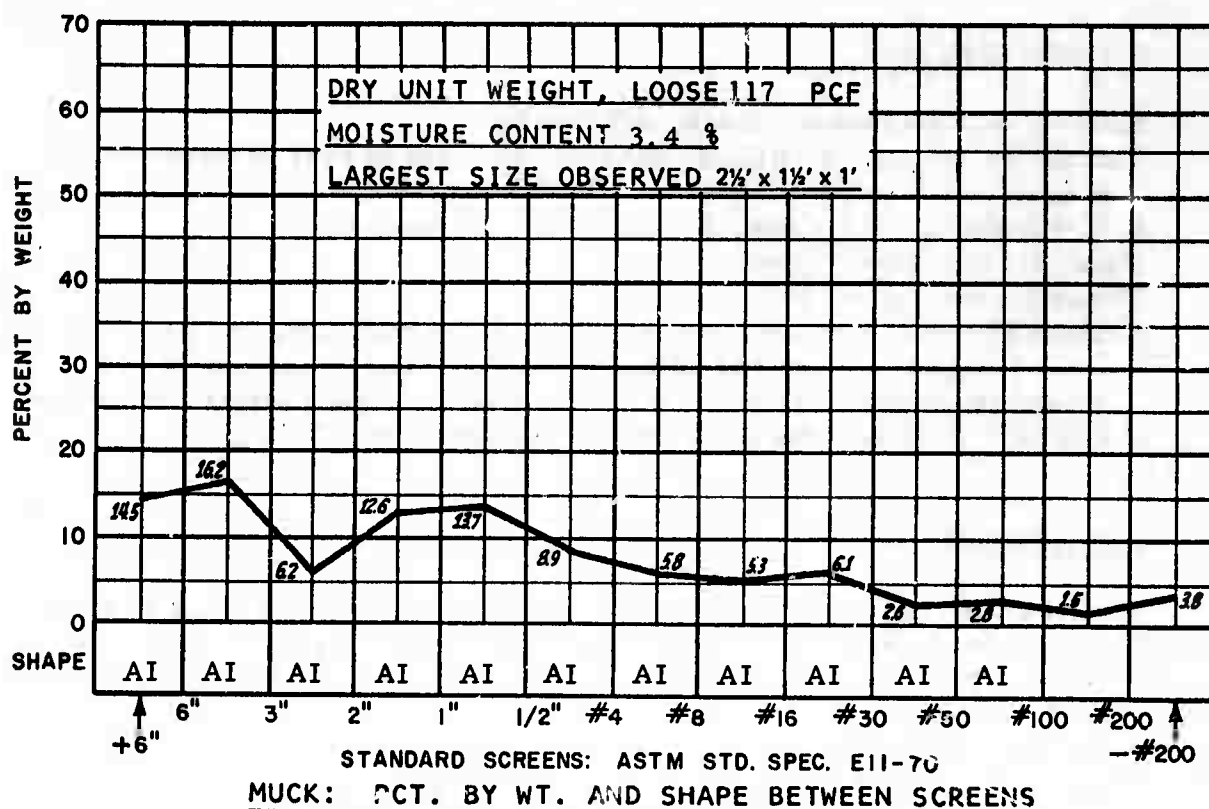
Shrinkage Limit 17.13 %  
Flow Index 4.10 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 2.8 % Moisture, 39°  
Angle Slide Steel Plate  
@ 2.8 % Moisture, 31°

Apparent Cohesion PSF  
@ 3.0 % Moisture, 80  
Bulk Density PCF  
@ 0.0 % Moisture, 91.2

Angle/Repose 10" Drop  
@ 2.8 % Moisture, 36°  
Angle Internal Friction  
@ 3.0 % Moisture, 38°



## SUMMARY

Rock Class: Igneous: Granite, biotitic, fine grained. Medium strength.  
RQD (Est.) 90%. DUW: 152 PCF. Ground water: Minor. Hardness: NA.

System Class: Conventional Rail. 10' high x 16' wide x 8' alcove. Two jack leg drills, 72-9' holes, double V-cut. PF 6.3#/CY. Mucking: Diesel front end loader, 1/2 CY. Haulage: Rail. Support: Grouted rock bolts and roof plates.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. NAST-3  
Sheet 2

### ROCK DATA:

Lithology: Igneous, granite, fine grained, moderately fractured, major quartz and minor feldspar and dark mineral contents.

Uniaxial Compressive Strength: 24 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 160 PCF.

Ground Water: Minor, primarily from fault zones.

Hardness: NA

### TUNNEL DATA:

Size: 9'-10" diameter. Grade: (+) 0.22%.

Ventilation System: 10 KCFM, exhaust, 22" pipe to rear of conveyor, 16" to face.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 5 to 20 gpm.

Power System: 4160/480V.

Haulage System: Muck, personnel, supplies by rail cars, 36" gage 70# rail.

Support System: 4" ring and half sets, at 4', 3' and 2' centers in bad ground (approximately 650'), 13" wide x 10' - 16 gage plates secured by 4-1" x 7' grouted bolts as required, (approximately 1200').

### EXCAVATION DATA:

Machine: Wirth Erkelenz, Hardrock Model (Modified)\*. Weight 67 tons.

Cutters: 29 Hughes Tool Tungsten Carbide Button. Gage: 6-11 1/2" TCB roller. Interior: 19-11 1/2" TCB roller. Center: 2-11 1/2" roller and 2-11 1/2" TCB cone.

Rotation: 8 1/2 RPM.

Torque: 150 K ft. # max., 125 K ft. # operating

Thrust: 630 K lbs.

Muck System: Bucket from face, 22" belt conveyor to rear.

Power System: 3-200 HP electric motor driven hydraulic pumps driving hydraulic motors and cylinders.

Guidance System: Laser.

\*Modified by replacement of original by a Hughes Tool Co. cutting head and cutters.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. NAST-4  
Sheet 1



# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056 : 0

Spec. Gravity, Material  
Size (-) 0.75 : 2.64

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 19.20%

Plastic Limit 18.97%

Shrinkage Limit 17.50%

Plasticity Index 0.23 %

Toughness Index 0.06 %

Flow Index 3.40 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 6.9 % Moisture, 39°

@ 7.1 % Moisture, 0

@ 6.9 % Moisture, 34°

Angle Slide Steel Plate

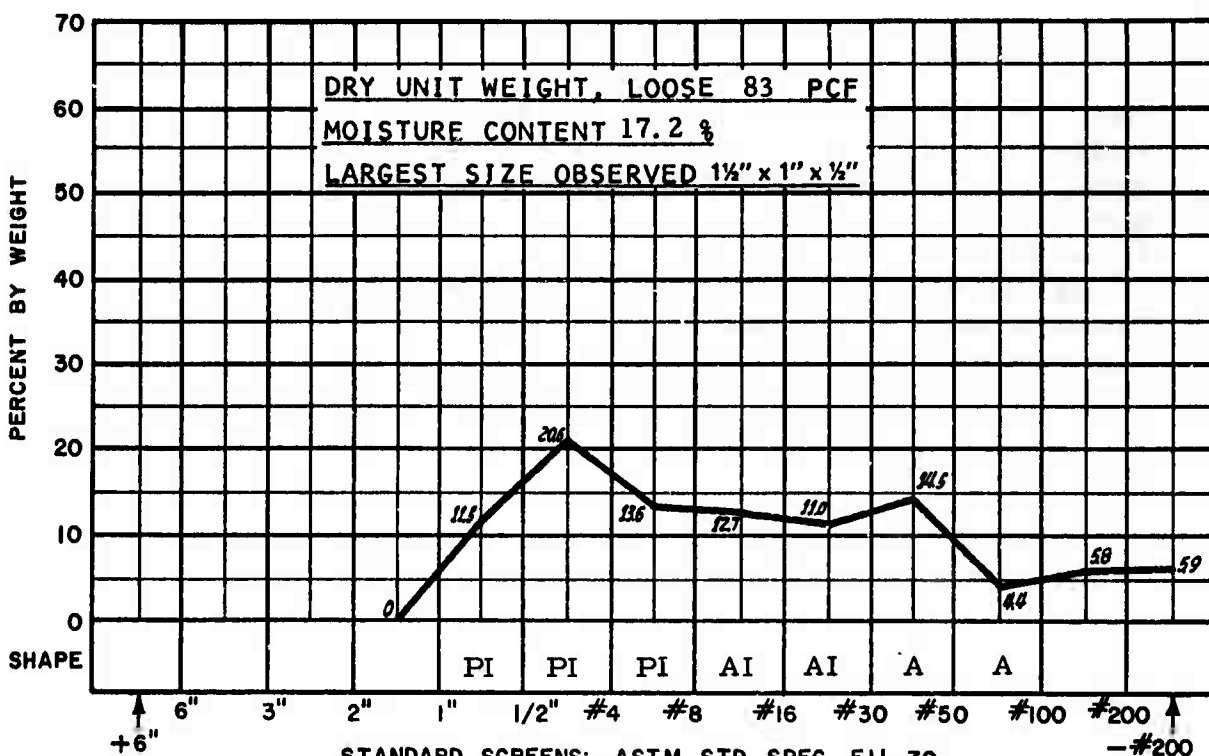
Bulk Density PCF

Angle Internal Friction

@ 6.9 % Moisture, 40°

@ 0.0 % Moisture, 91

@ 7.1 % Moisture, 33°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Igneous: Granite, fine grained, moderately fractured. High strength. RQD (Est.) 90%. DUW: 160 PCF. Ground water: Minor. Hardness: NA

System Class: TBM, Wirth Erkelenz, Hardrock, with Hughes Tool head, 9' 10" dia. 29 Hughes Tool TCB roller and cone cutters. RPM: 8 1/2. 125 K ft # torque, 630 K# thrust. Mucking: Buckets to belt. Haulage: Rail. Support: 4" ring and half sets, roof plates and rock bolts.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. NAST-4  
Sheet 2

#### ROCK DATA:

Lithology: Igneous, granite, massive, major feldspar and quartz, minor dark mineral content.

Uniaxial Compressive Strength: 35 KPSI

RQD: (Estimated) 96%

Dry Unit Weight: 161 PCF

Ground Water: Minor, through fractures.

Hardness: NA

#### TUNNEL DATA:

Size: 10' x 10' Horse shoe. Grade (-) 0.22%

Ventilation System: 8 KCFM, exhaust, 22" pipe.

Utility System: 6" air line, 2" water line

Water Inflow: 5-10 gpm.

Power System: 110V. lighting

Haulage System: Muck and supplies: Eimco 912 diesel.

Support System: 4" WF steel sets @ 4' in 180' approx. at portal end; 1" x 7' grouted rock bolts for approx. 35'.

#### EXCAVATION DATA:

Conventional Trackless System.

Drilling: Crawler Jumbo, 2-D93 Drifters, 10' feeds.

Drill Round: 48-1 3/4" holes, double V cut, 8' depth.

Explosives: 175# Gelex #2-70%. Powder factor, 6.1#/CY.

Blasting: Electrical, regular delays, zero through #10.

Mucking System: Eimco 912 diesel, front end loader.

Guidance: Transit lines.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056": 0

Spec. Gravity, Material  
Size (-) 0.75": 2.59

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 16.20 %

Plastic Limit 15.78 %

Shrinkage Limit 13.67 %

Plasticity Index 0.42 %

Toughness Index 0.14 %

Flow Index 3.00 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 0.9 % Moisture, 39°

@ 0.9 % Moisture, 215

@ 0.9 % Moisture, 36°

Angle Slide Steel Plate

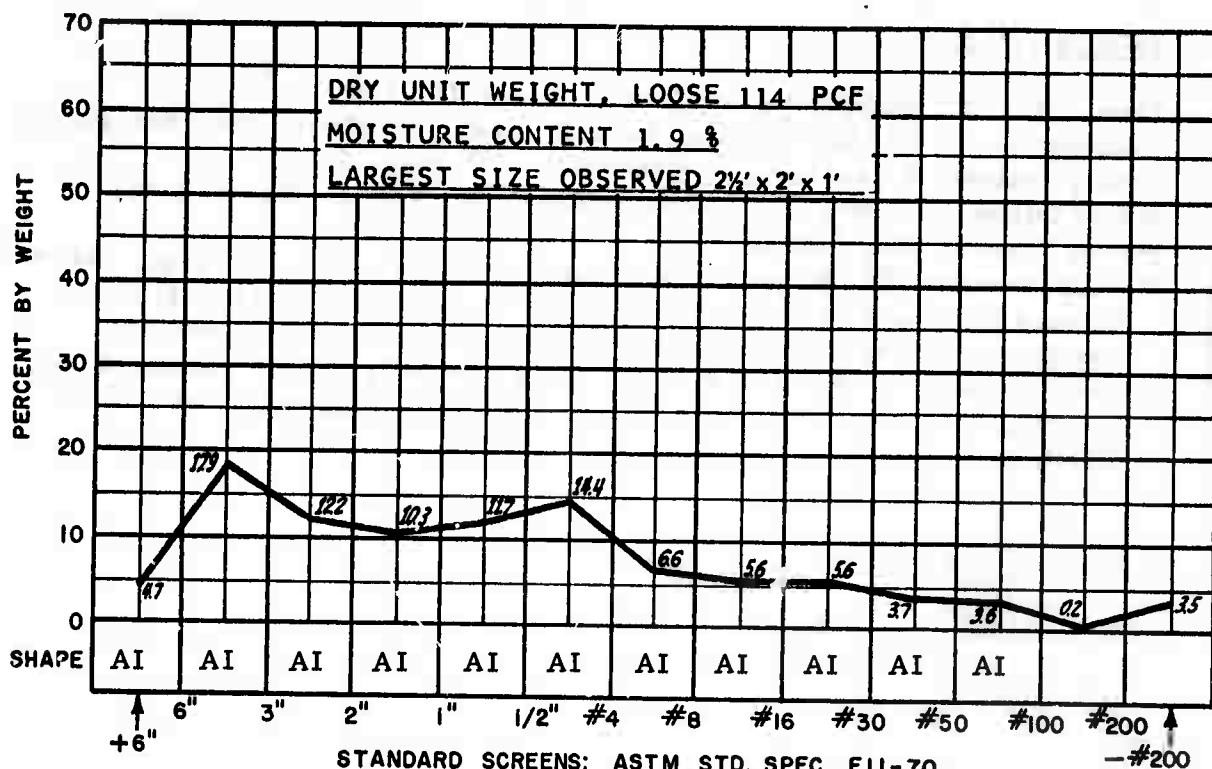
Bulk Density PCF

Angle Internal Friction

@ 0.9 % Moisture, 34°

@ 0.0 % Moisture, 106

@ 0.9 % Moisture, 46°



## SUMMARY

Rock Class: Igneous: Granite, massive, minor dark minerals. Very high strength. RQD (Est.) 96%. DUW: 161 PCF. Ground water: Minor. Hardness: NA

System Class: Conventional Trackless. 10' x 10' arch. Two machine jumbo, 48-8' holes, V-cut. PF 6.1 #/CY. Front end loader mucking and haulage. Support: Steel sets at 4', 25%, occasional rock bolts in 730'.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. GA-1  
Sheet 2

### ROCK DATA:

Lithology: Igneous, granite, gray, fine grained, moderately jointed with 1.5' to 2' bands of light tan pegmatite and laminated granite gneiss.  
Uniaxial Compressive Strength: 32 KPSI.  
RQD: (Estimated) 80%.  
Dry Unit Weight: 162 PCF.  
Ground Water: Formations generally dry.  
Hardness: NA

### TUNNEL DATA:

Size: 10' x 10', Modified Horseshoe. Grade: (+) 1/4%  
Ventilation: 15 KCFM, exhaust, 26" dia. pipe, 125 HP at 7200' from portal.  
Utility System: 8" air line, 4" water line, 10" pump line.  
Water Inflow: 20 GPM. (As much as 400 GPM in occasional pockets)  
Power System: 4160/440V.  
Haulage System: Muck, personnel, supplies by rail cars, 36" gage, 75# rail.  
Three-15T. Goodman locomotives; 2 trains of 11 to 13 cars @ 4.8 CY.  
Canton car transfer at 50' to 250' from face, passing tracks @1500'.  
Support System: 4" WF sets @ 4', 3' and 2' for 23%, 1" x 7' grouted bolts for 17%, Shotcrete: 500 psi @ 18 hrs., 3750 psi @ 28 days, for 16% of 7200'.

### EXCAVATION DATA

Conventional Rail System.  
Drilling: Rail mounted hydrojib jumbo, 4-CF99, & 1-CF133 drifters, 12' feed.  
Drill Round: 38 holes, 1-5" center hole and 37 at 1 3/4" dia. Spiral Burn Cut, 10 1/2' depth.  
Explosives: 183 lbs. Gelex #2-75% x 1-1/2" dia., and 20 lbs. Smooth-tex 70% x 7/8" dia. in upper perimeter holes. Powder factor: 5 1/2# /CY.  
Blasting: Electrical, regular delays zero through 10.  
Mucking: EIMCO #25, rail, air operated.  
Guidance: Laser

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. H-1  
Sheet 1

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056" : 0

Spec. Gravity, Material  
Size(-)0.75" : 2.70

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.0%  
Plasticity Index 1.0 %

Plastic Limit 17.0 %  
Toughness Index 0.23 %

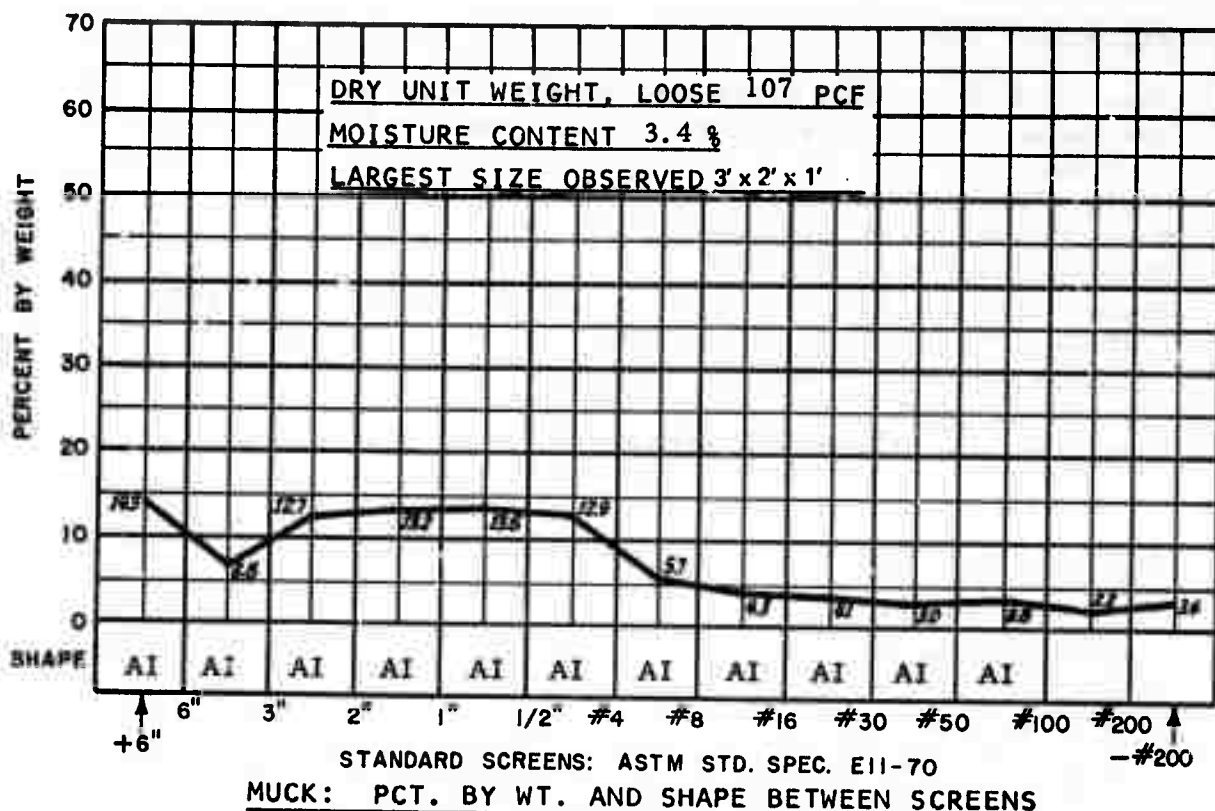
Shrinkage Limit 13.4 %  
Flow Index 4.4 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 1.3 % Moisture, 40°  
Angle Slide Steel Plate  
@ 1.3 % Moisture, 32°

Apparent Cohesion PSF  
@ % Moisture, NA  
Bulk Density PCF  
@ % Moisture, NA

Angle/Repose 10" Drop  
@ 1.3 % Moisture, 37°  
Angle Internal Friction  
@ 2.2 % Moisture, 44°



## SUMMARY

**Rock Class:** Igneous: Granite, fine grained, with 1.5' to 2' bands of pegmatite and laminated granite gneiss. High strength. RQD (Est.) 80%. DUW: 162 PCF. Ground water: Minor. Hardness: NA.

**System Class:** Conventional Rail. 10' x 10' arch. Five machine jumbo, 38 10-1/2' holes, burn cut. PF 5.5#/CY. Overhead loader mucking, rail haulage. Support: Steel sets at 2' to 4', 23%, rockbolts 17%, shotcrete 16%, in 7200'.

MDN STUDY  
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SYSTEM DATA SHEET  
MDN

Ident. No. H-1  
Sheet 2

ROCK DATA:

Lithology: Igneous, granite, gray, gneissic, moderately jointed.  
Uniaxial Compressive Strength: 39 KPSI  
RQD: (Estimated) 80%  
Dry Unit Weight: 164 PCF  
Ground Water: Generally dry - occasional flows through fractures  
Hardness: NA

TUNNEL DATA:

Size: 10' x 10' modified horseshoe. Grade: (+) 1/4%  
Ventilation System: 8 KCFM exhaust, 26" pipe, 150 HP at 10,000 from portal.  
Utility System: 8" air line, 4" water line, 10" pump line  
Water Inflow: 20-400 GPM, normal 135 GPM  
Power System: 4160/480/240V.  
Haulage System: Muck, personnel, supplies by rail cars, 36" gage, 75# rail. Three-15T. Goodman locomotives, 3 trains of 5 to 7 cars @ 4.8 cy. Canton car transfers at 50' to 250' from face, passing tracks @ 1500' to 2500'.  
Support System: Minor rock bolt support for last 2500'.

EXCAVATION DATA:

Conventional Rail System  
Drilling: 4 boom Hydrojib jumbo, 4-CF99 + 1-CF133 drifters, 12' contin. feed.  
Drill Round: 36-40 holes, 1 3/4" diameter, 11' deep, spiral burn cut with 5" center hole.  
Explosives: 200 lbs. 75% Gelex #2, 25 lbs. 30% Dupont 7/8" x 24" in back holes.  
Blasting: Electrical, regular delays 0-10, Powder factor 5.6#/CY.  
Mucking: EIMCO #25, rail, air operated  
Guidance: Laser

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-)0.056" : 0

Spec. Gravity, Material  
Size (-)0.75" : 2.60

## ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 18.10%  
Plasticity Index 0.15 %

Plastic Limit 17.95 %  
Toughness Index 0.04 %

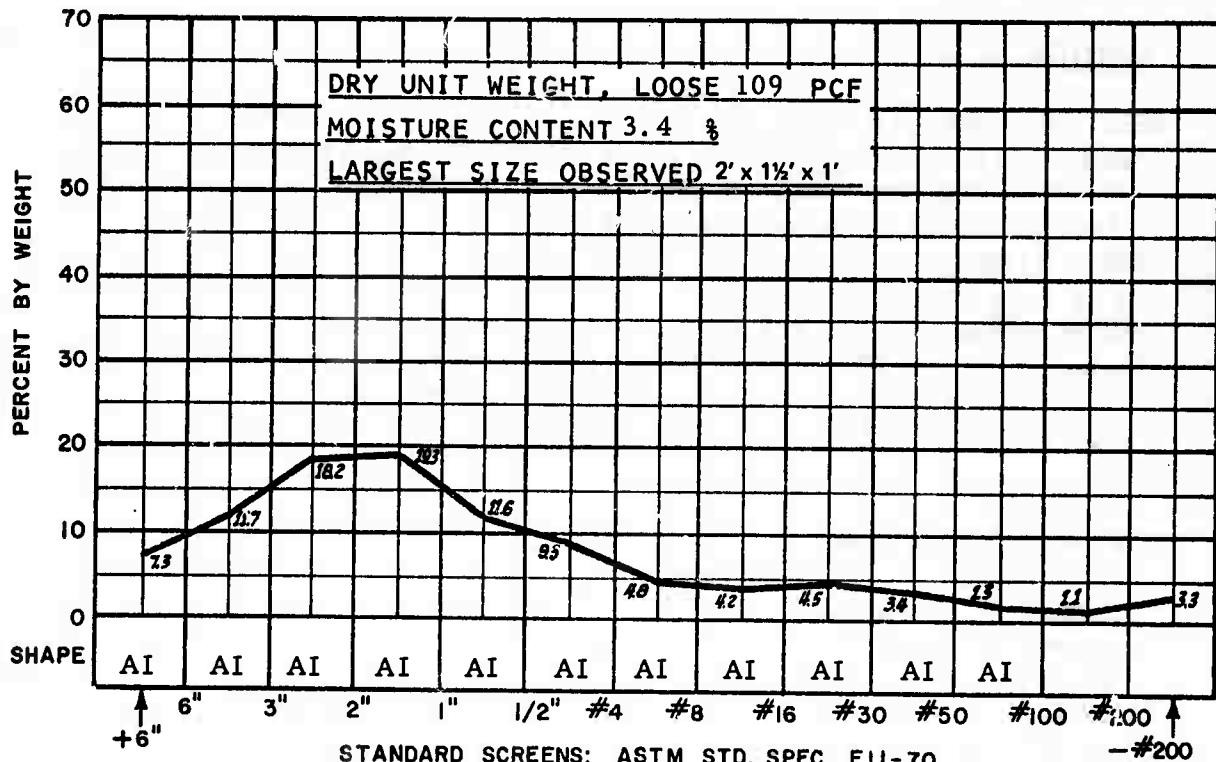
Shrinkage Limit 11.00 %  
Flow Index 3.20 %

## MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop  
@ 3.8 % Moisture, 38°  
Angle Slide Steel Plate  
@ 3.8 % Moisture, 38°

Apparent Cohesion PSF  
@ 2.6 % Moisture, 30  
Bulk Density PCF  
@ 0.0 % Moisture, 105

Angle/Repose 10" Drop  
@ 3.8 % Moisture, 35°  
Angle Internal Friction  
@ 2.6 % Moisture, 44°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Igneous: Granite, gneissic, moderately jointed. Very high strength.  
RQD (Est.) 80%. DUW: 164 PCF. Ground water: Minor. Hardness: NA

System Class: Conventional Rail. 10' x 10' arch. Five machine jumbo,  
36 to 40 - 11' holes, burn cut. PF 5.6#/CY. Overhead loader mucking - rail  
haulage. Support: occasional rock bolts 7200' to 10,000'.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. H-2  
Sheet 2

#### ROCK DATA:

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry.

Uniaxial Compressive Strength: 25 KPSI

RQD: (Estimated) 83%

Dry Unit Weight: 162 PCF.

Ground Water: None apparent

Hardness: NA

#### TUNNEL DATA:

Size: 18' wide x 16' high, arched back. Grade: (+) 5 1/2%.

Ventilation System: 76 KCFM, pressure in heading, 48" pipe and tubing.

Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HF, 2 stage, surface fans.

Utility System: 6" compressed air, 2" water.

Water Inflow: None apparent.

Power System: 4160/220V for fans, 110 volt lighting.

Haulage System: Wagner ST8 Scooptram to raise, chute loaded into rail mounted skip. Personnel and supplies by diesel truck.

Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts @ 4'.

#### EXCAVATION DATA:

Conventional Trackless System

Drilling: Gardner-Denver 3 boom jumbo, 1 PR123 and 2 DH 123 drifters, 12' feeds.

Drill Round: 47 holes, 1 3/4" diameter, including 6 hole burn cut, and 1 center hole, 4" diameter, all 10 1/2' deep.

Explosives: 25# - 1 1/2" x 8", 60% or 75% primers, 25# - 7/8" x 16", 30% in trim holes, 40# - 1 1/2" x 16", 45% in 6 hole burn cut, and 275# AN/FO in remainder of round. Powder factor: 4#/cy.

Blasting: Electrical, regular delays, 0 through 15.

Mucking: Scooptram.

Guidance: Laser.



# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-)0.056" : 0

Spec. Gravity, Material  
Size (-)0.75" : 2.85

## ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 18.10 %

Plastic Limit 17.98 %

Shrinkage Limit 17.69 %

Plasticity Index 0.12 %

Toughness Index 0.30 %

Flow Index 3.90 %

## MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop  
@ 0.8 % Moisture, 33°

Apparent Cohesion PSF  
@ 0.4 % Moisture, 435

Angle/Repose 10" Drop  
@ 0.8 % Moisture, 30°

Angle Slide Steel Plate

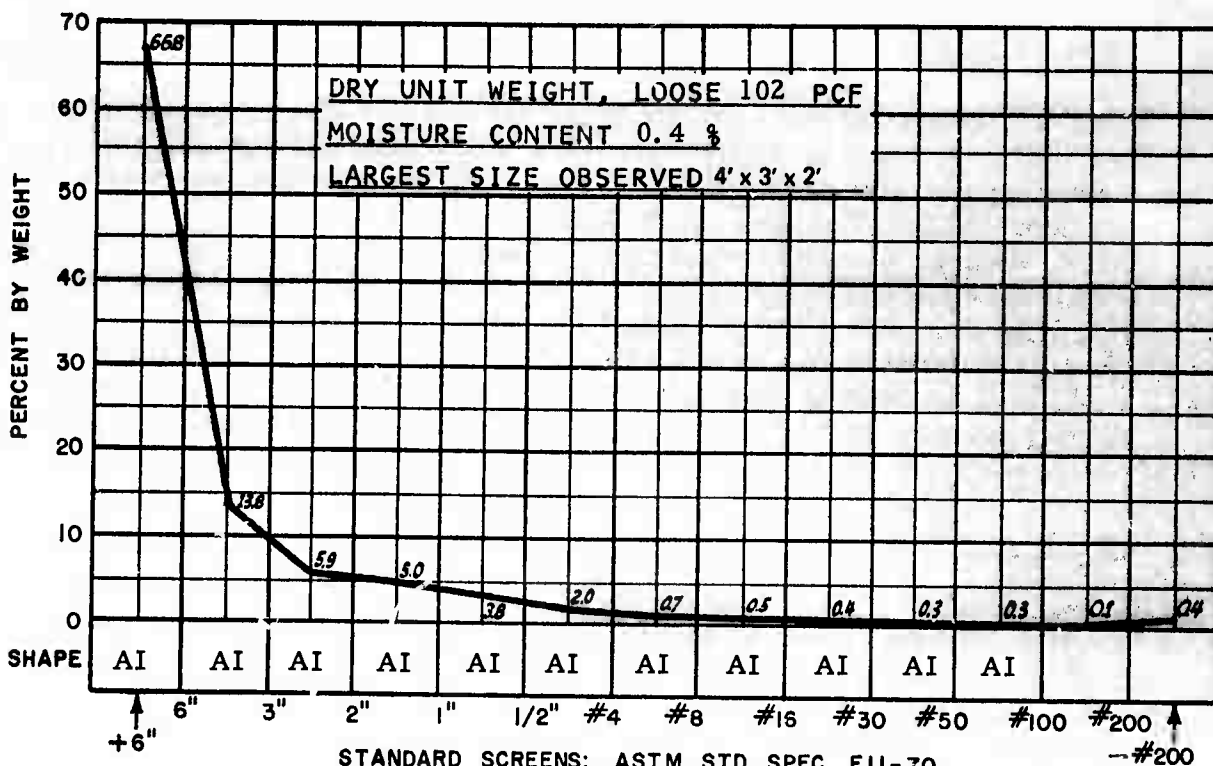
Bulk Density PCF

Angle Internal Friction

@ 0.8 % Moisture, 29°

@ 0.0 % Moisture, 97.3

@ 0.4 % Moisture, 43°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry. High strength. RQD (Est.) 83%. DUW: 162 PCF. Ground Water: Dry. Hardness: NA.

System Class: Conventional Trackless. 18' wide x 16' arch. Three boom jumbo, 47-10 1/2' holes, burn cut PF 4#/CY. Scooptram mucking and haulage to raise-rail skip to surface. Support: Roof plates and rock bolts at 4'.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LK-1  
Sheet 2

### ROCK DATA:

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry, with minor steeply inclined joints.  
Uniaxial Compressive Strength: 28 KPSI  
RQD: (Estimated) 83%  
Dry Unit Weight: 165 PCF  
Ground Water: None apparent  
Hardness: NA

### TUNNEL DATA:

Size: 18' wide x 16' high, arched back. Grade: (+) 2%.  
Ventilation System: 22 KCFM, pressure in heading, 48" pipe and tubing.  
Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage surface fans.  
Utility System: 6" compressed air, 2" water.  
Water Inflow: None apparent.  
Power System: 4160/220 for pumps and fans, 110V lighting.  
Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station, rail mounted skip to surface. Personnel and supplies by diesel truck.  
Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts @ 4'.

### EXCAVATION DATA:

Conventional Trackless system.  
Drilling: Gardner-Denver 3 boom jumbo, 3 PR123 drifters, 12' feeds.  
Drill Round: 47 holes, 1 3/4" diameter, including 6 hole burn cut, and 1 center hole, 4" diameter, all 10 1/2' deep.  
Explosives: 25#-1 1/2" x 8", 60% or 75% primers, 25#-7/8" x 16", 30% in trim holes, 40#-1 1/2" x 16", 45% in 6 hole burn cut, and 275# AN/FO in remainder of round. Powder factor: 4#/CY.  
Blasting: Electrical, regular delays, 0 through 15.  
Mucking: Scooptram.  
Guidance: Laser.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LK-2  
Sheet 1

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-)0.056" : 0

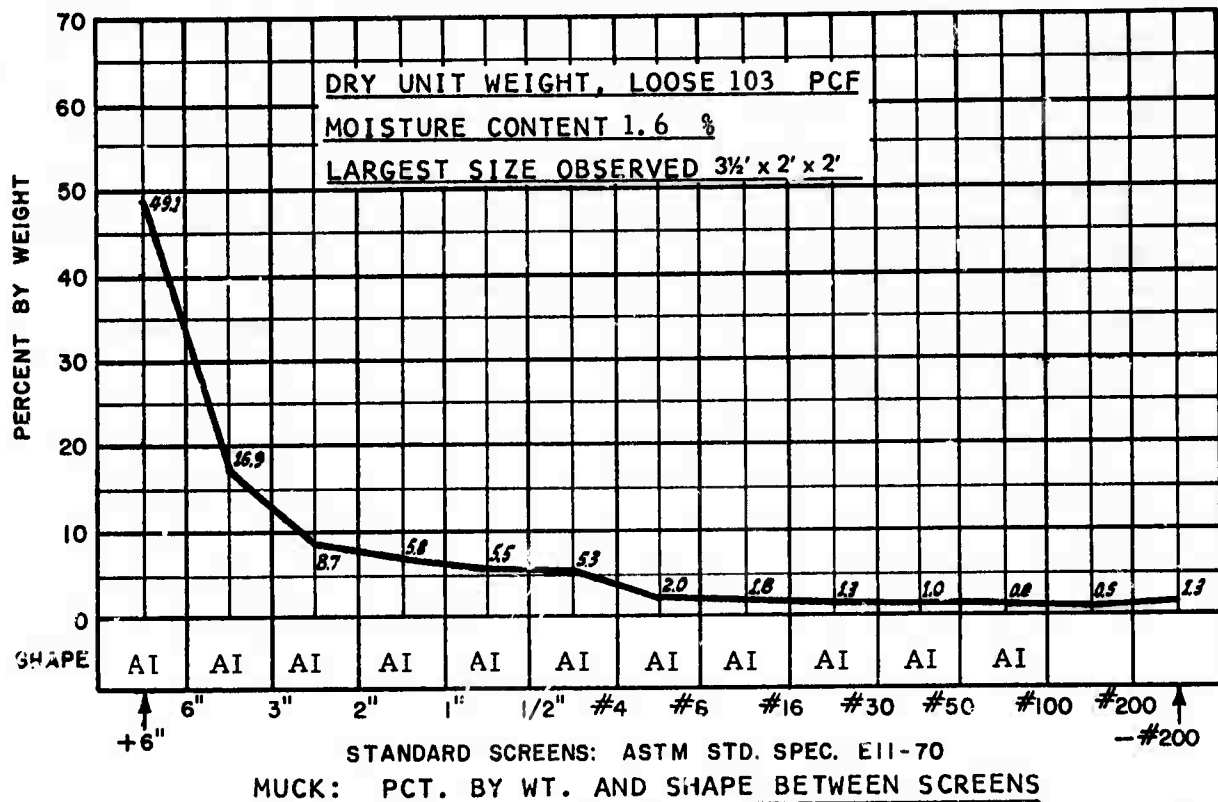
Spec. Gravity, Material  
Size (-)0.75": 2.73

## ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 20.50% Plastic Limit 19.14% Shrinkage Limit 17.29 %  
Plasticity Index 0.36 % Toughness Index 0.058 % Flow Index 6.2 %

## MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop Apparent Cohesion PSF Angle/Repose 10" Drop  
@ 4.7 % Moisture, 43° @ 4.9 % Moisture, 210 @ 4.7 % Moisture, 42°  
Angle Slide Steel Plate Bulk Density PCF Angle Internal Friction  
@ 4.7 % Moisture, 33° @ 0.0 % Moisture, 97.6 @ 4.9 % Moisture, 39°



## SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry, minor steep angle joints. High strength. RQD (Est.) 83%.  
DUW: 165 PCF. Ground water: Dry. Hardness: NA

System Class: Conventional Trackless. 18' wide x 16' arch. Three boom jumbo, 47 - 10 1/2' holes, burn cut. PF 4#/CY. Scooptram mucking and haulage, rail skip to surface. Support: Roof plates and rock bolts at 4'.

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9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LK-2  
Sheet 2

#### ROCK DATA:

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry.

Uniaxial Compressive Strength: 32 KPSI

RQD: (Estimated) 92%

Dry Unit Weight: 165 PCF

Ground Water: None apparent.

Hardness: NA

#### TUNNEL DATA:

Size: 12' diameter vertical bore hole, reamed from 1312' to 1212' below collar, from a 13 7/8" diameter pilot hole.

Ventilation System: None in bore hole.

Utility System: 5 to 10 gpm. Water for dust suppression through pilot hole.

Water Inflow: None apparent

Power System: 440V to surface drive motors.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/  
rail mounted skip to surface.

Support System: None in bore hole.

#### EXCAVATION DATA:

Machine: Robbins H81R Raise Drill. Weight 49 tons. Cutters: 27 Robbins, Steel Disc. Gage: 3-12". Center: 1-11". Interior: 19-12" single and 2-11" twin. Two sets of three 12" dia. TCB roller stabilizers are installed on third points below the cutter head.

Rotation, cutter head: 6 RPM.

Torque: 260 K Foot Lbs. Full Load.

Reaming Full: Total 814K Lbs @ 2400 FSI, net 507 K#.

Muck Disposal: Scooptram, underground.

Power System: 3-440V, 100 HP motors, 1.667: 1 gathering  
box ratio.

Guidance System: Survey in pilot hole.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-)0.056" : 0

Spec. Gravity, Material  
Size (-)0.056": 2.67

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 25.00 %

Plastic Limit 20.95 %

Shrinkage Limit 19.68 %

Plasticity Index 4.05 %

Toughness Index 0.73 %

Flow Index 5.50 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 3.4 % Moisture, 33°

@ 3.0 % Moisture, 75

@ 3.4 % Moisture, 32°

Angle Slide Steel Plate

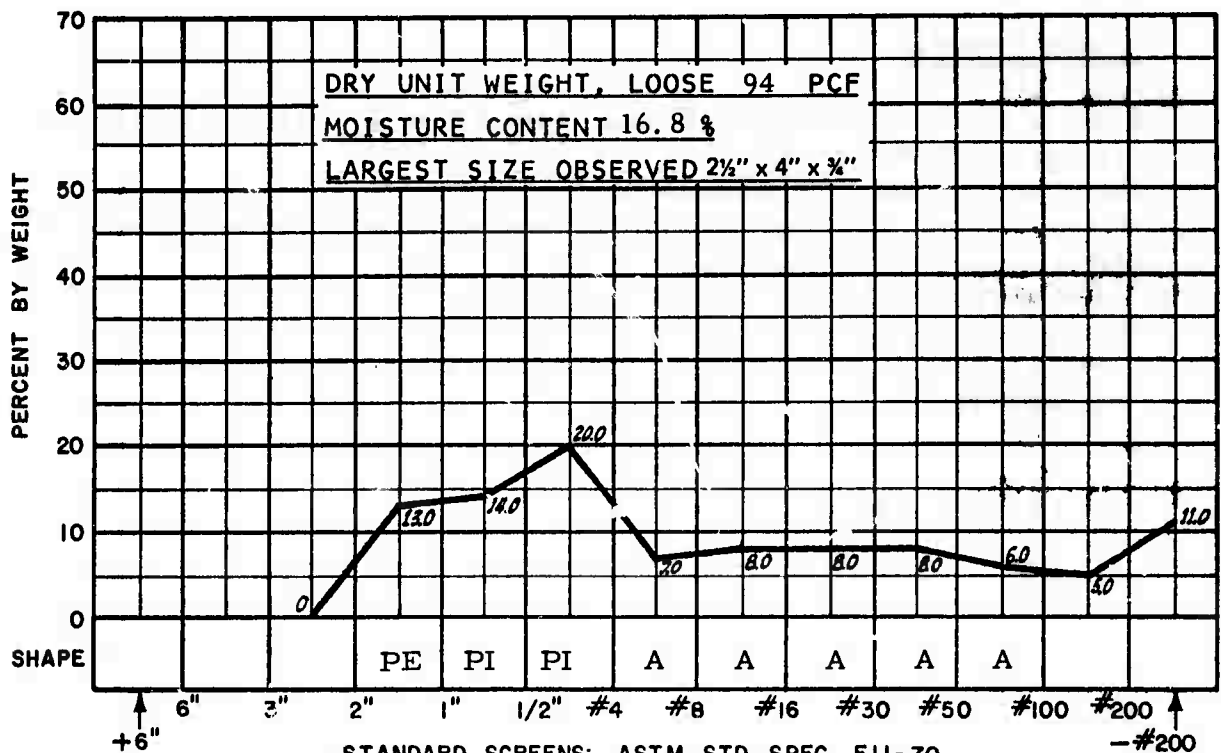
Bulk Density PCF

Angle Internal Friction

@ 3.4 % Moisture, 38°

@ 0.0 % Moisture, 100

@ 3.0 % Moisture, 37°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry. High strength. RQD (Est.) 92%, DUW: 165 PCF. Ground water: Dry. Hardness: NA.

System Class: RBM, Robbins H81R, 12' dia. 27 Robbins disc cutters, 6 RPM, 383.5 Kft. # torque, 507 K# pull average. Mucking and haulage: Scooptram underground, rail skip to surface. Support: None.

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9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LK-5  
Sheet 2

#### ROCK DATA:

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry, frequent flat angled joints.

Uniaxial Compressive Strength: (Estimated) 7 KPSI

RQD: (Estimated) 86%.

Dry Unit Weight: 137 PCF.

Ground Water: None apparent.

Hardness: N.A.

#### TUNNEL DATA:

Size: 4' diameter vertical bore hole reamed from 298' to 286' below collar from a 13 7/8" diameter pilot hole.

Ventilation System: Not applicable.

Utility System: 5 to 10 gpm water for dust suppression through pilot hole.

Water Inflow: None apparent.

Power System: 440V to surface drive motors.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/ rail mounted skip to surface. Personnel and supplies by diesel truck.

Support System: None in bore hole.

#### EXCAVATION DATA:

Machine: Robbins H81R Raise Drill. Weight: 49 tons.

Cutters: 11-Robbins, Steel Disc. Gage: 1-12" twin. Center 1-12" single.

Interior: 4-12" twin. Three 12" TCB roller stabilizers are installed at third points below the cutter head.

Rotation, Cutter head: 6 RPM

Torque: 260 K Foot/lbs. Full Load

Reaming Pull: Net 207K#

Muck Disposal: Scooptram underground.

Power System: 3-440V, 100 HP motors, 1.667: 1 gathering box ratio.

Guidance System: Survey in pilot hole.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-)0.056" : 0

Spec. Gravity, Material  
Size (-)0.75" : 2.53

## ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 19.40 %

Plastic Limit 18.16 %

Shrinkage Limit 17.27 %

Plasticity Index 1.24 %

Toughness Index 0.31 %

Flow Index 4.00 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 3.7 % Moisture, 30°

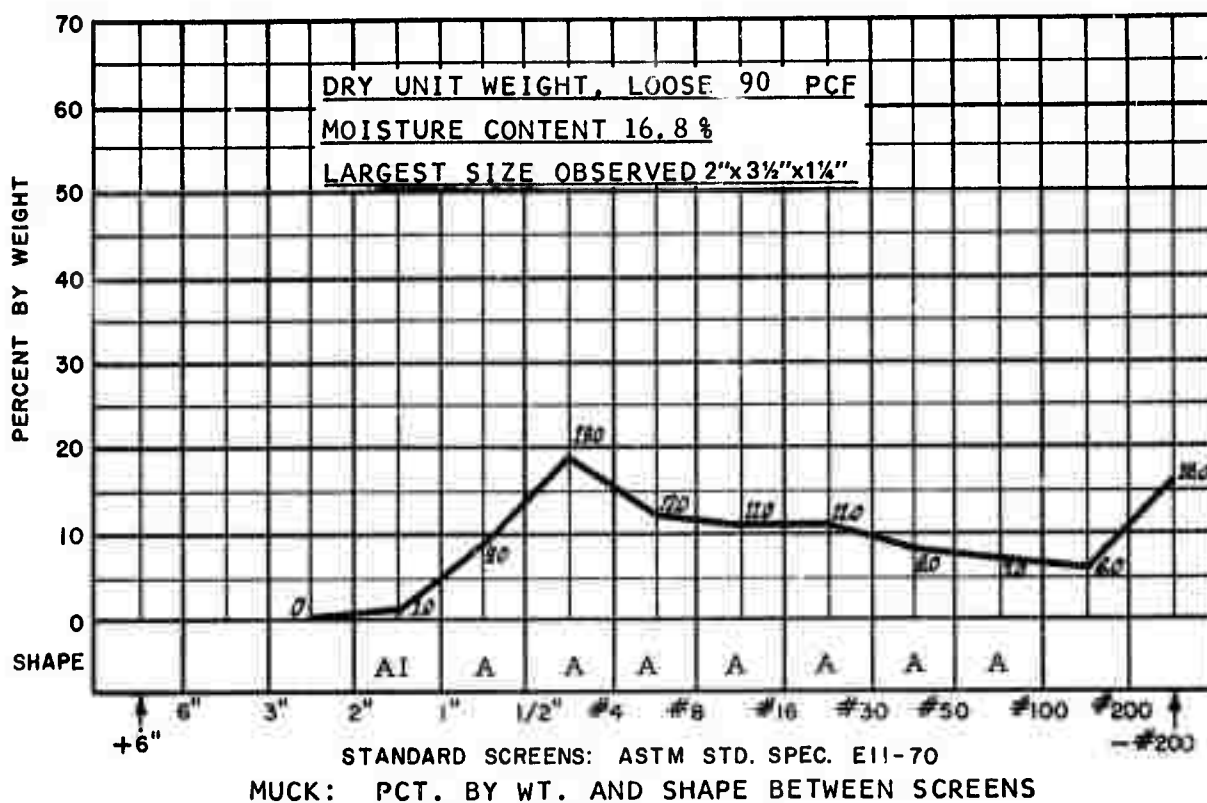
Apparent Cohesion PSF  
@ 0.2 % Moisture, 0

Angle/Repose 10" Drop  
@ 3.7 % Moisture, 29°

Angle Slide Steel Plate  
@ 3.7 % Moisture, 32°

Bulk Density PCF  
@ 0.0 % Moisture, 101

Angle Internal Friction  
@ 0.2 % Moisture, 40°



## SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry, frequent flat angled joints. Low strength (Est.). RQD (Est.) 86%.  
DUW: 137 PCF. Ground water: Dry. Hardness: NA.

System Class: RBM, Robbins H81R, 4' dia. 11 Robbins disc cutters. 6 RPM, 260 K ft # torque, 207 K # pull (average). Mucking and Haulage: Scooptram underground, rail skip to surface. Support: None.

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9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LK-6  
Sheet 2

#### ROCK DATA:

Lithology: Igneous, quartz monzonite porphyry, intensely altered, coarse grained.

Uniaxial Compressive Strength: 7 KPSI.

RQD: (Estimated) 35%.

Dry Unit Weight: 158 PCF

Ground Water: None

Hardness: N.A.

#### TUNNEL DATA:

Size: 15' wide x 14' high, arched back. Grade: (-) 26%.

Ventilation System: 22 KCFM, pressure, 48" pipe and tubing, 150 HP @ 650'.

Utility System: 6" air, 2" water, 4" pump line.

Water Inflow: Minor

Power System: 4160/220, 110V lighting.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/rail mounted skip to surface. Personnel and supplies by Diesel truck.

Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts at 4'.

#### EXCAVATION DATA:

Conventional Trackless System.

Drilling: Three boom hydrojib jumbo, w/PR123 drifters on 12' feeds.

Drill Round: 42 holes, 1 3/4" diameter, including 6 hole burn cut, and 1-4" diameter center hole, all 10 1/2' deep.

Explosives: 25#-1 1/2" x 8", 60% as primers, 25#-7/8" x 16", 30% in trim holes, 300#-1 1/2" x 16" in remainder of round. Powder factor: 4.7#/CY.

Blasting: Electrical, regular delays 0 through 15.

Mucking System: Scooptram

Guidance: Laser.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LK-7  
Sheet 1



# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056" : 0

Spec. Gravity, Material  
Size (-) 0.75" : 2.68

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.00%  
Plasticity Index 0.88 %

Plastic Limit 17.12 %  
Toughness Index 0.18 %

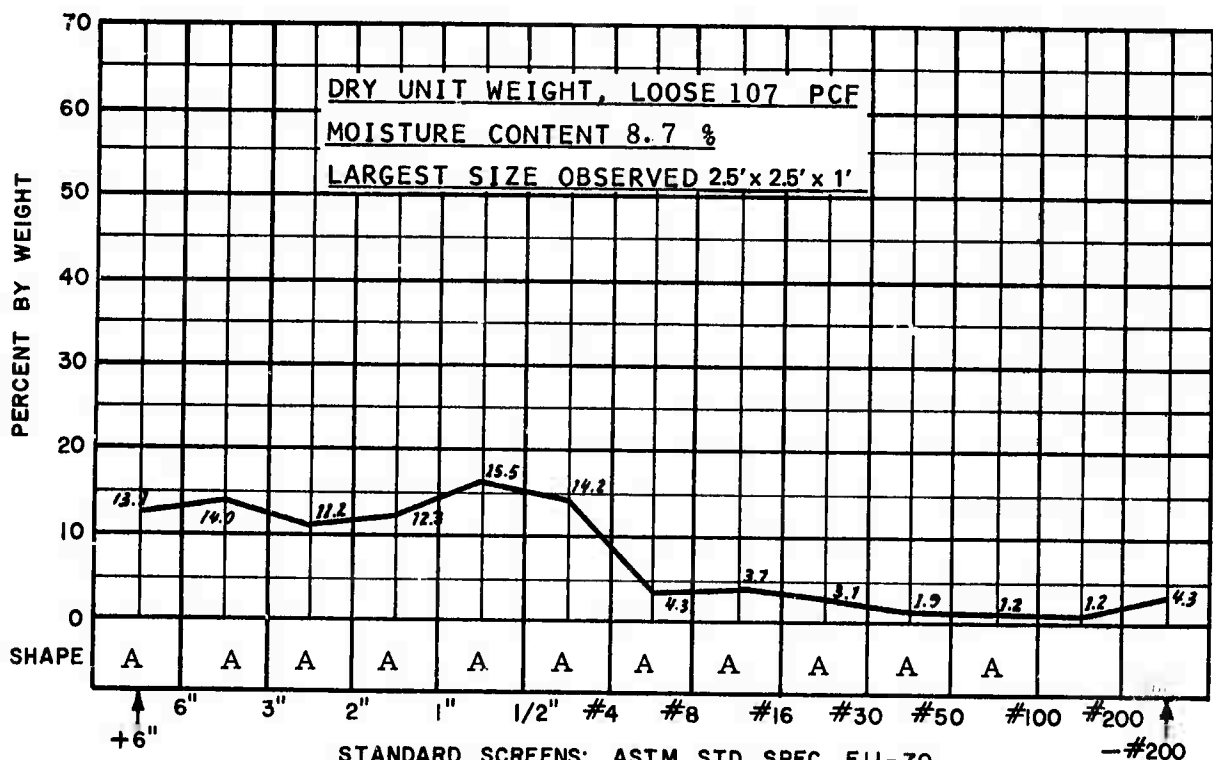
Shrinkage Limit 17.04 %  
Flow Index 5.00 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 1.7 % Moisture, 29°  
Angle Slide Steel Plate  
@ 1.7 % Moisture, 28°

Apparent Cohesion PSF  
@ 0.2 % Moisture, 70  
Bulk Density PCF  
@ 0.0 % Moisture, 114

Angle/Repose 10" Drop  
@ 1.7 % Moisture, 26°  
Angle Internal Friction  
@ 0.2 % Moisture, 45°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Igneous: Quartz monzonite porphyry, intensely altered, coarse grained. Low strength. RQD (Est.) 85%. DUW: 158 PCF. Ground water: None. Hardness: N.A.

System Class: Conventional Trackless, 15' wide x 14' arch. Three boom jumbo, 42-10 1/2' holes, burn cut. PF 4.7 #/CY. Scooptram mucking and haulage rail skip to surface. Support: Roof plates and rock bolts at 4'.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LK-7  
Sheet 2

#### ROCK DATA:

Lithology: Igneous, quartz monzonite, coarse grained with many sulfide veinlets, highly fractured, pronounced orthogonal faulting.  
Uniaxial Compressive Strength: 19K.  
RQD: (Estimated) 50%.  
Dry Unit Weight: 165 PCF  
Ground Water: Saturated below working levels.  
Hardness: N.A.

#### TUNNEL DATA:

Size: 12' x 12' Grade: (+) 0.4%  
Ventilation System: 14 KCFM, pressure, 24" diameter pipe, 60 HP @ 400' from airway.  
Utility System: 2" water, 4" airline, 8" pump line.  
Water Inflow: None upper levels, 20-200 gpm lower levels.  
Power System: 2400/480/240/110.  
Haulage System: Muck, supplies, personnel by railcars, 8 ton battery locomotives, 10 ton bottom dump devel. cars, 36" gage, 45# rail.  
Support System: 10 1/2' x 12" x 12" wood posts, 12" H beam cap sets at 5' centers in normal ground.

#### EXCAVATION DATA:

Conventional Rail System.  
Drilling: 3 boom hydrojib jumbo, CF79 drifters on 6' shells or D89 drifters on 6' chain feeds.  
Drill Round: 52 holes, 1 5/8" diameter, including 2 hole wedge burn and 4 relievers, 5' depth.  
Explosives: 100# Carbamite per round (Amogel in wet ground).  
Blasting: #6 caps, 8' fuse, timed by order of connection to igniter cord.  
(Primacord used in place of primer powder) Powder factor 3.8#/CY.  
Mucking System: Eimco 40 loader.  
Guidance: Transit survey.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident No. SM-1  
Sheet 1

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size(-) 0.056" : 0

Spec. Gravity, Material  
Size(-) 0.75" : 2.72

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 12.50 %

Plastic Limit 11.02 %

Shrinkage Limit 10.52 %

Plasticity Index 1.48 %

Toughness Index 0.29 %

Flow Index 5.1 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 0.2 % Moisture, 36°

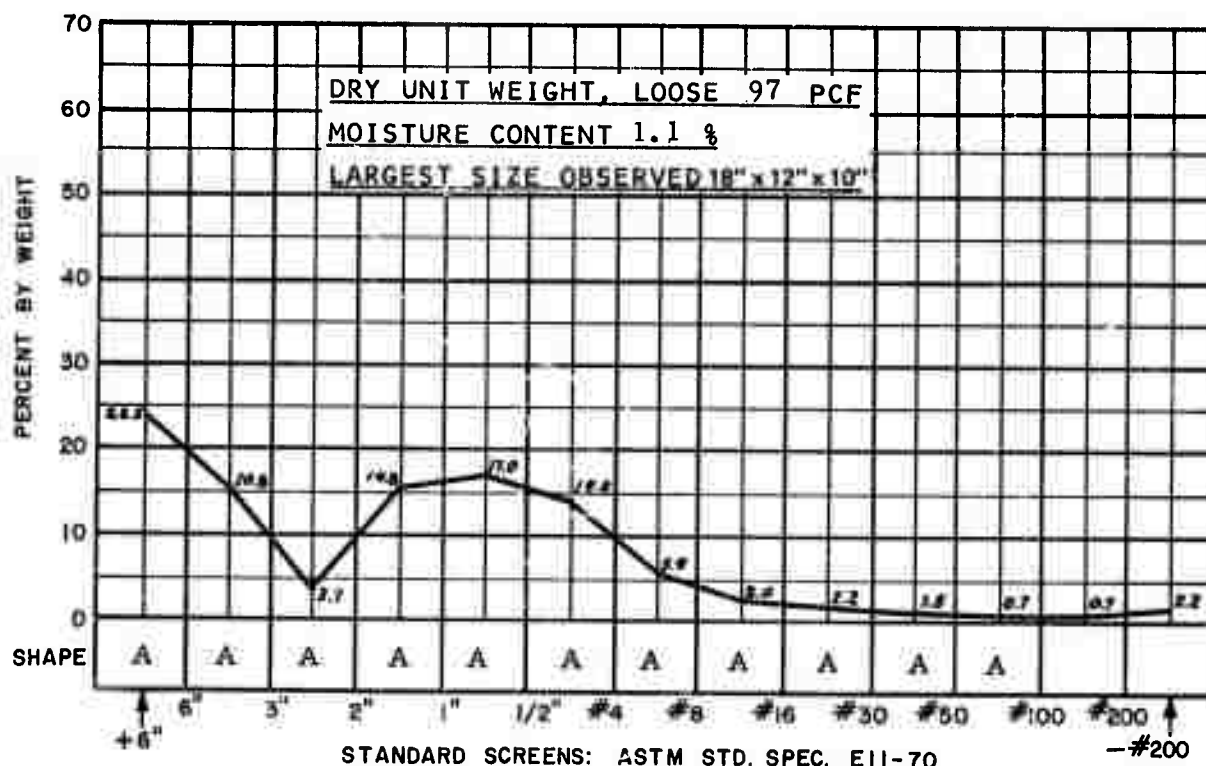
Apparent Cohesion PSF  
@ 0.2 % Moisture, 90

Angle/Repose 10" Drop  
@ 0.2 % Moisture, 31°

Angle Slide Steel Plate  
@ 0.2 % Moisture, 28°

Bulk Density PCF  
@ 0.0 % Moisture, 112

Angle Internal Friction  
@ 0.2 % Moisture, 44°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Igneous: Quartz monzonite, coarse grained, many sulfide veinlets. Highly fractured, pronounced orthogonal faulting. High strength. RQD (Est.) 50%.  
DUW: 165 PCF. Ground water: Dry. Hardness: N.A.

System Class: Conventional Rail. 12' x 12'. Three boom jumbo, 52-5' holes, wedge cut. PF 3.8#/CY. Eimco 40 mucker. Haulage: Rail. Support: Wood posts and steel cap at 5'.

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9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. SM-1  
Sheet 2

#### ROCK DATA:

Lithology: Metamorphic, granitic gneiss, highly metamorphosed, moderately to highly fractured, highly silicified.  
Uniaxial Compressive Strength: 9 KPSI.  
RQD: (Estimated) 10%.  
Dry Unit Weight: 174 PCF.  
Ground Water: Minimal-drains to other workings.  
Hardness: NA

#### TUNNEL DATA:

Size: 13', round, Grade (+) 1/4 percent.  
Ventilation System: 10 K CFM. exhaust, 24" pipe  
Utility System: 4" air line, 2" water line.  
Water Inflow: 5-10 gpm.  
Power System: 4160/480V.  
Haulage System: Personnel, muck, supplies by rail cars.  
Support System: None.

#### EXCAVATION DATA:

Machine: Calweld, Hardrock model, #40.  
Weight: 200 tons.  
Cutters: 19-Smith Tool Tungsten Carbide Button, Gage: 6-GT-SH 8 roller.  
Center: 1-TCB 24" tricone, interior: 12-GT-MH8 roller.  
Rotation: Center cutter-26 RPM, Head-12 RPM.  
Torque: 347 K # max.  
Thrust: 1,128 K #. 677 K# operating  
Muck Collection: Buckets from face, 24" conveyor to rear.  
Power System: 480V Electro-Hydraulic, 825 HP.  
Guidance System: Laser.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size : NA

Spec. Gravity, Material  
Size : NA

## ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %

Plastic Limit NA %

Shrinkage Limit NA %

Plasticity Index NA %

Toughness Index NA %

Flow Index NA %

## MATERIAL SIZE

IN.

Angle/Repose 1" Drop  
@ % Moisture, NA

Apparent Cohesion PSF  
@ % Moisture, NA

Angle/Repose 10" Drop  
@ % Moisture, NA

Angle Slide Steel Plate

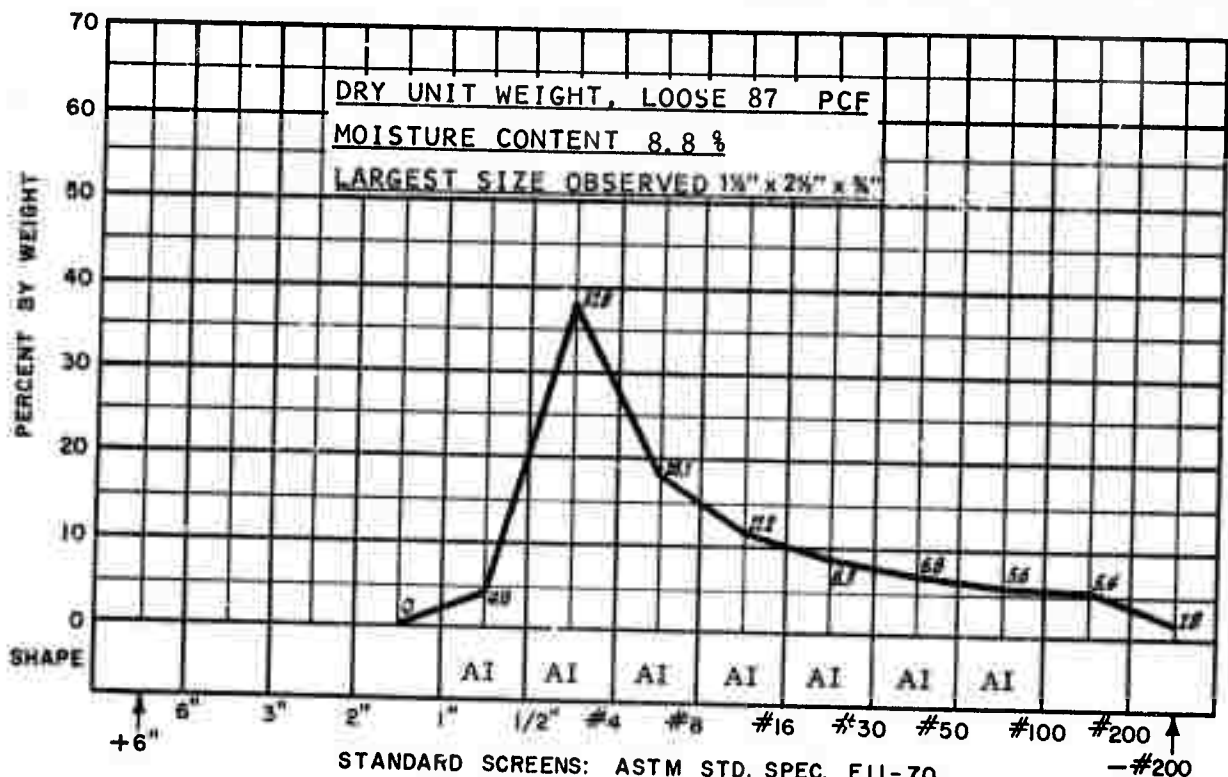
Bulk Density PCF

Angle Internal Friction

@ % Moisture, NA

@ % Moisture, NA

@ % Moisture, NA



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Metamorphic: Granitic gneiss, highly metamorphosed and silicified, moderately to highly fractured. RQD: (Est.) 10%. DUW: 174 PCF. Medium strength. Ground water: Dry. Hardness: NA

System Class: TBM, Calweld #40, 13' dia. 19 Smith Tool TCB roller and tricone cutters. RPM: Head 12, center 26. 347K ft # torque, 677 K# thrust. Mucking: Buckets to belt. Haulage: Rail. Support: None.

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9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. CL-1  
Sheet 2

### ROCK DATA:

Lithology: Metamorphic, interlayered transition between quartzite and tactite. Moderately to strongly altered metasediments, with replacement pyrite, chalcopyrite and magnetite, and a high percentage of silicates, very fine to medium grained.

Uniaxial Compressive Strength: 26 KPSI.

RQD: (Estimated) 80%

Dry Unit Weight: 178 PCF.

Ground Water: None apparent

Hardness: NA

### TUNNEL DATA:

Size: 16' wide x 14 1/2' high, arched back. Grade: (+) 2%.

Ventilation System: 52 KCFM, pressure in heading, 48" pipe and tubing.

Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage surface fans.

Utility System: 6" compressed air, 2" water.

Water Inflow: None apparent.

Power System: 4160/220V for pumps and fans, 110V lighting.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/rail mounted skip to surface. Personnel and supplies by diesel truck.

Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts at 4'.

### EXCAVATION DATA:

Conventional Trackless System.

Drilling: Gardner-Denver 3 boom jumbo, 3 PR123 drifters, 12' feeds.

Drill Round: 42 holes, 1 3/4" diameter, including 6 hole burn cut, and 1 center hole, 4" diameter, all 6' deep.

Explosives: 15# - 1 1/2" x 8", 60% or 75% as primers, 15# - 7/8" x 16", 30% in trim holes, 25# - 1 1/2" x 16", 45% in 6 hole burn cut, 150#

AN/FO in remainder of round. Powder factor 5#/cy.

Blasting: Electrical, regular delays, 0 through 15.

Mucking: Scooptram.

Guidance: Laser.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LK-3  
Sheet 1

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056" : 0

Spec. Gravity, Material  
Size (-) 0.75" : 3.21

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.25 %  
Plasticity Index 0.33 %

Plastic Limit 17.92 %  
Toughness Index 0.06 %

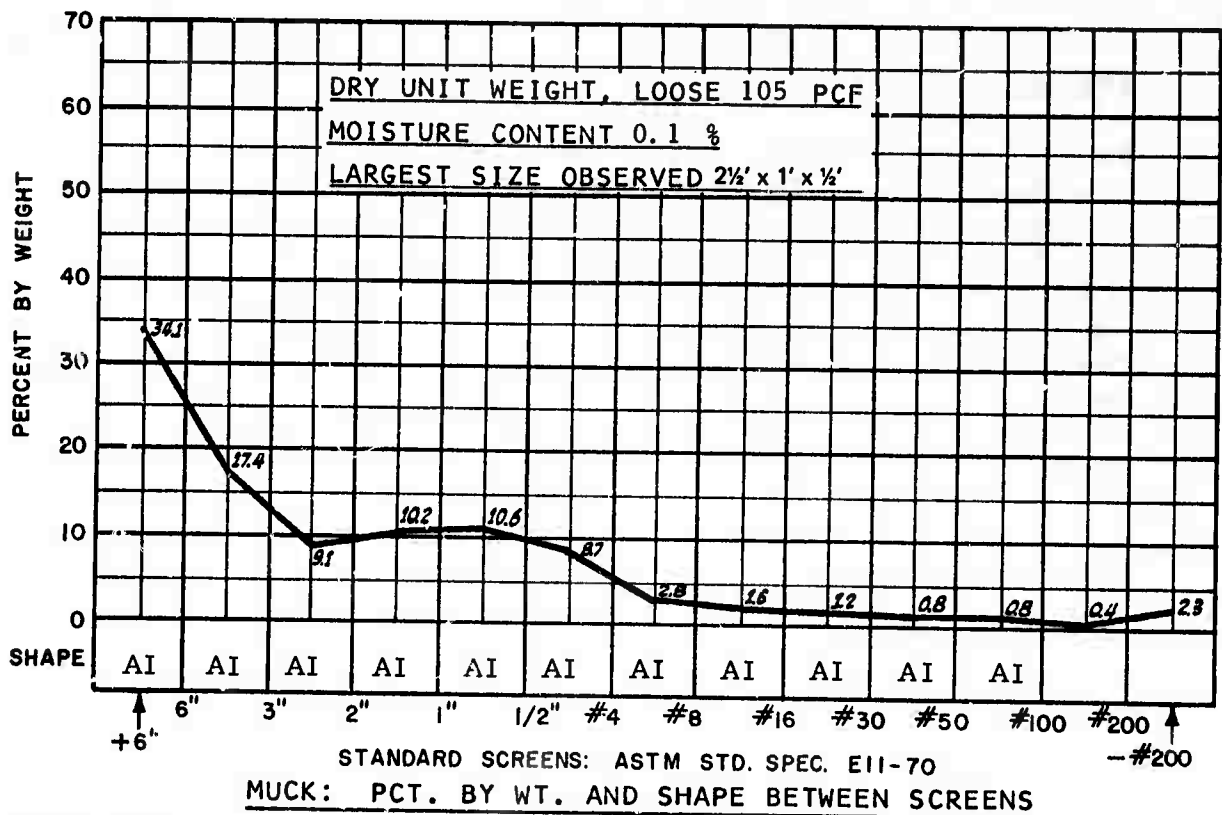
Shrinkage Limit 17.80 %  
Flow Index 5.50 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 1.5 % Moisture, 30°  
Angle Slide Steel Plate  
@ 1.5 % Moisture, 29°

Apparent Cohesion PSF  
@ 0.4 % Moisture, 175  
Bulk Density PCF  
@ 0.0 % Moisture, 117.8

Angle/Repose 10" Drop  
@ 1.5 % Moisture, 29°  
Angle Internal Friction  
@ 0.4 % Moisture, 41°



## SUMMARY

Rock Class: Metamorphic: Quartzite-tactite transition, very fine to medium grained, with replacement sulphides and magnetite, high in silicates. High strength. RQD:(Est.) 80%. DUW: 178 PCF. Ground water: Dry. Hardness: NA.  
System Class: Conventional Trackless. 16' wide x 14-1/2' arch. Three boom jumbo, 42-6' holes, burn cut. PF 5#/CY. Scooptram mucking and haulage, rail skip to surface. Support: Roof plates and rock bolts at 4'.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LK-3  
Sheet 2

#### ROCK DATA:

Lithology: Metamorphic, tactite, strongly altered calcareous metasediments, with replacement pyrite, chalcopyrite and magnetite, and a high percentage of silicates, fine to very fine grained.

Uniaxial Compressive Strength: 14 KPSI

RQD: (Estimated) 70%

Dry Unit Weight: 181 PCF

Ground Water: None apparent.

Hardness: NA

#### TUNNEL DATA:

Size: 15' wide x 14' high, arched back. Grade: (+) 2%.

Ventilation System: 50 KCFM, pressure in heading, 48" pipe and tubing.

Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage surface fans.

Utility System: 6" compressed air, 2" water.

Water Inflow: None apparent.

Power System: 4160/220V for pumps and fans, 110V lighting.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/rail mounted skip to surface. Personnel and supplies by diesel truck.

Support System: 6" WF Steel Sets at 5'.

#### EXCAVATION DATA:

Conventional Trackless System:

Drilling: Gardner-Denver 3 boom jumbo, 3 PR123 drifters, 12' feeds.

Drill Round: 42 holes, 1 3/4" diameter, including 6 hole burn cut and 1 center hole, 4" diameter; all 6' deep.

Explosives: 15#-1 1/2" x 8", 60% or 75% as primers, 15#- 8" x 16" 30% in trim holes, 25#-1 1/2" x 16", 45% in 6 hole burn cut, 150# AN/FO in remainder of round. Powder factor 5.5#/CY.

Blasting: Electrical, regular delays, 0 through 15

Mucking: Scooptram.

Guidance: Laser



# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056" : 0

Spec. Gravity, Material  
Size (-) 0.75" : 3.36

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 19.00%

Plastic Limit 17.95 %

Shrinkage Limit 16.43 %

Plasticity Index 1.05 %

Toughness Index 0.19 %

Flow Index 5.40 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 2.0 % Moisture, 37°

@ 0.2 % Moisture, 165

@ 2.0 % Moisture, 35°

Angle Slide Steel Plate

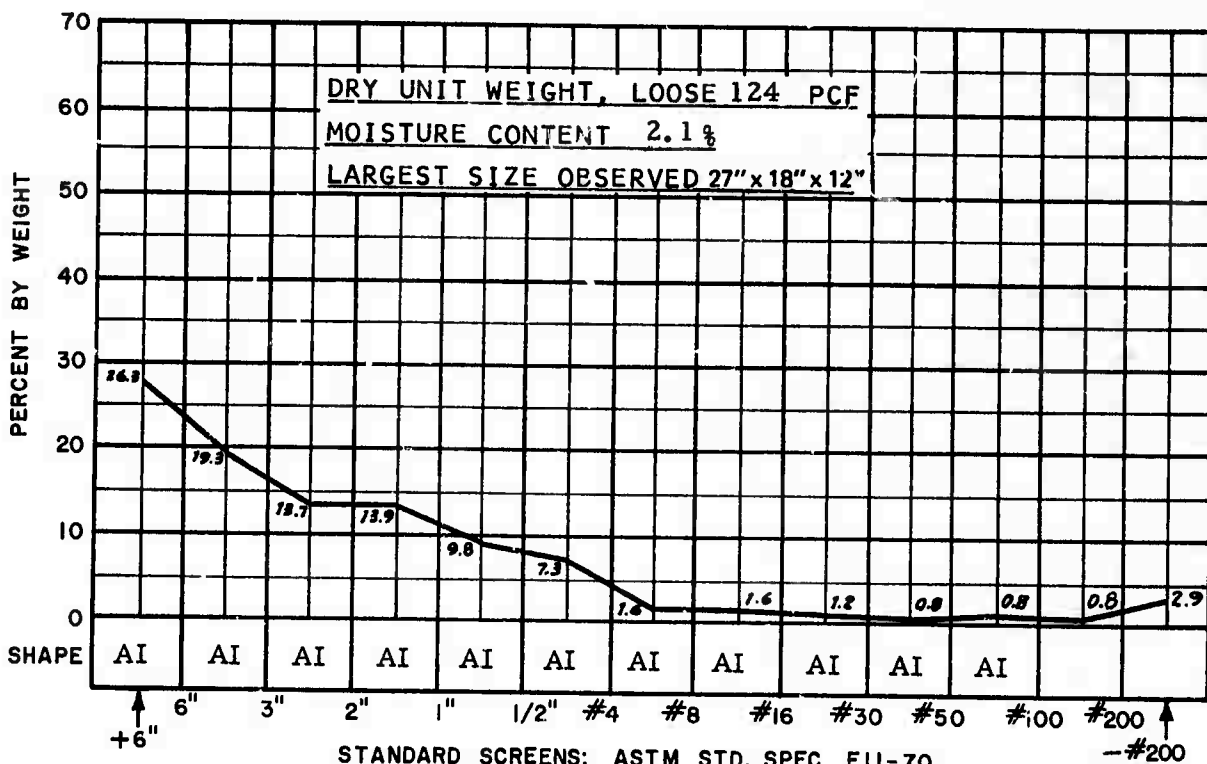
Bulk Density PCF

Angle Internal Friction

@ 2.0 % Moisture, 30°

@ 0.0 % Moisture, 115

@ 0.2 % Moisture, 43°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Metamorphic: Tactite, fine to very fine grained, with replacement sulphides and magnetite, high in silicates. Medium strength (Est.).  
RQD (Est.) 70%. DUW: 181 PCF. Ground water: Dry. Hardness: N.A.

System Class: Conventional Trackless. 15' wide x 14' arch. Three boom jumbo, 42-6' holes, burn cut. PF 5.5#/CY. Scooptram mucking and haulage, rail skip to surface. Support. Steel sets at 5'.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LK-4  
Sheet 2

### ROCK DATA:

Lithology: Metamorphic, interlayered bands of hematite and martite, highly jointed, normally flat lying, but often highly folded. Natural iron over 60%, silica 5%.

Uniaxial Compressive Strength: 7 KPSI.

RQD: (Estimated) 10%

Dry Unit Weight: 207 PCF

Ground Water: Formation generally dry.

Hardness: NA

### TUNNEL DATA:

9'-11 1/2" diameter; normal grade: 0%.

Ventilation System: 3 KCFM, pressure, 8" dia. tube, 5 HP @ 250' from main level.

Utilities: 2" air line, 1" water line, 2-1 1/2" pressure and 1-3" return hydraulic lines.

Water Inflow: None

Power System: 110V lighting, 440V to scraper hoist.

Muck Haulage: 30 HP hoist, and 42" scraper to raise, all rail on main level.

Personnel, rail and ladders; supplies by rail cars and hoist.

Support: Continuous; 9'-6" dia. x 4" WF sets at 45".

### EXCAVATION DATA:

Machine: Calweld Oscillator. Wt: 69 K#.

Cutters: 278 Carboloy drag bits. Gage: 20 rippers (experimental).

Interior: 258 "J" tools.

Rotation: 8 RPM

Torque: 1200 K ft. #.

Thrust: 300 K# max., 285 K# operating.

Anchorage: Thrust on installed sets, 285K# operating.

Muck Collection: Flight conveyor to rear of machine, removal by scraper.

Power System: Remote power unit; 2-90 gpm, 2500 psi hydraulic pumps and 125 HP motors on main level; thrust and rotation through hydraulic cylinders.

Guidance System: Survey.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-)0.056" : 0

Spec. Gravity, Material  
Size (-) 0.75" : 4.34

## ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 17.8 %

Plastic Limit 15.1 %

Shrinkage Limit 13.9 %

Plasticity Index 2.7 %

Toughness Index 0.66 %

Flow Index 4.1 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 6.2 % Moisture, 37°

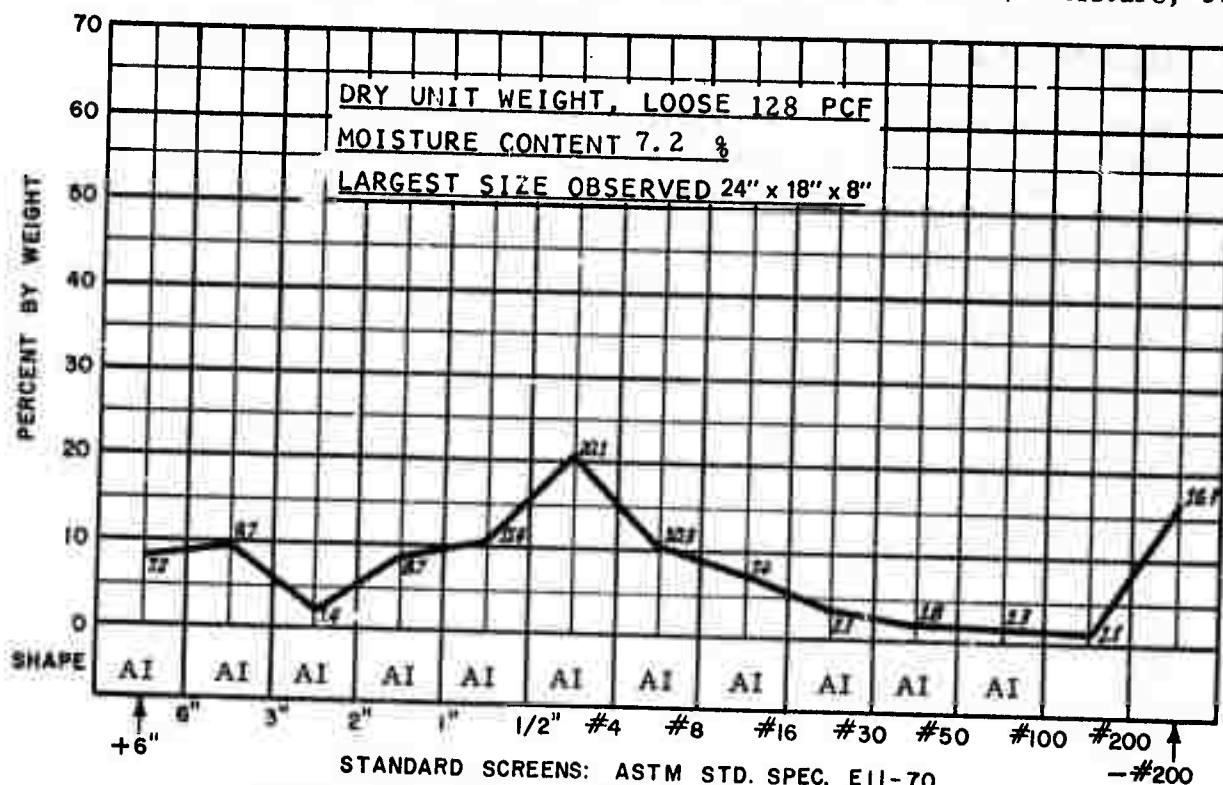
Apparent Cohesion PSF  
@ 6.9 % Moisture, 235

Angle/Repose 10" Drop  
@ 6.2 % Moisture, 35°

Angle Slide Steel Plate  
@ 6.2 % Moisture, 31°

Bulk Density PCF  
@ 0.0 % Moisture, 141

Angle Internal Friction  
@ 6.9 % Moisture, 35°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Metamorphic: Hematite and martite interlayered, highly jointed, bedding normally flat, often highly folded. Low strength. RQD (Est.) 10%.  
DUW: 207 PCF. Ground water: Dry. Hardness: NA.

System Class: TBM, oscillator, Calweld #53, 9'11 1/2" dia. 278 Carboloy drag bits. 8 RPM, 1200 K ft# torque, 285 K# thrust. Mucking: Flight conveyor and scraper to raise. Haulage: Rail. Support: Continuous, 9'6" dia. x 4" H sets at 45".

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. MB-1  
Sheet 2

#### ROCK DATA:

Lithology: Metamorphic, interlayered hematite and martite, highly jointed, normally flat lying, often highly folded. Natural iron over 60%, silica 5%.  
Uniaxial Compressive Strength: NA PSI  
RQD: (Estimated) 10%.  
Dry Unit Weight: NA  
Ground Water: None  
Hardness: NA

#### TUNNEL DATA:

Size: 10' wide x 9'-6" (7' cap and 8' post). Grade: Level  
Ventilation System: 4 KCFM pressure, 8" diameter pipe and tubing, 15 HP @ 600', and 8" exhaust, 5 HP @ 100'.  
Utility System: 2" airline, 1" water line  
Water Inflow: None  
Power System: 2300/440V.  
Haulage System Muck, 30 HP hoist and 48" scraper from surge pile at rear of miner to chute - 160 CF cars, 30 ton tandem locomotives on 30" gage 60# rail to shaft pocket, 14 ton skips to surface.  
Support System: 8"-58# WF sets, 7' cap, 8' post, at 4'-5", wood lagging and pipe spiling, 8-1" diameter or 6-2" diameter in back.

#### EXCAVATION DATA:

Machine: Alpine, Model F-6A Total Weight: 11 tons.  
Cutters: 68 Kennametal 43 KH carbide tipped "plumb bob" type, mounted on twin ripper heads at 90° to boom.  
Rotation: 60 RPM about horizontal axis; boom moved vertically and horizontally by hydraulic cylinders.  
Torque: 49.6 HP.  
Thrust: Sumping thrust from 2-10 HP crawler motors.  
Anchor Pressure: Crawlers only.  
Muck Collection: Central 14" flight conveyor fed by two gathering arms on inclined apron, discharging to surge pile.  
Power System: 440V.  
Guidance: Transit lines.

MUCK DATA      Test Data NA.

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size :

Spec. Gravity, Material  
Size :

ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit %  
Plasticity Index %

Plastic Limit %  
Toughness Index %

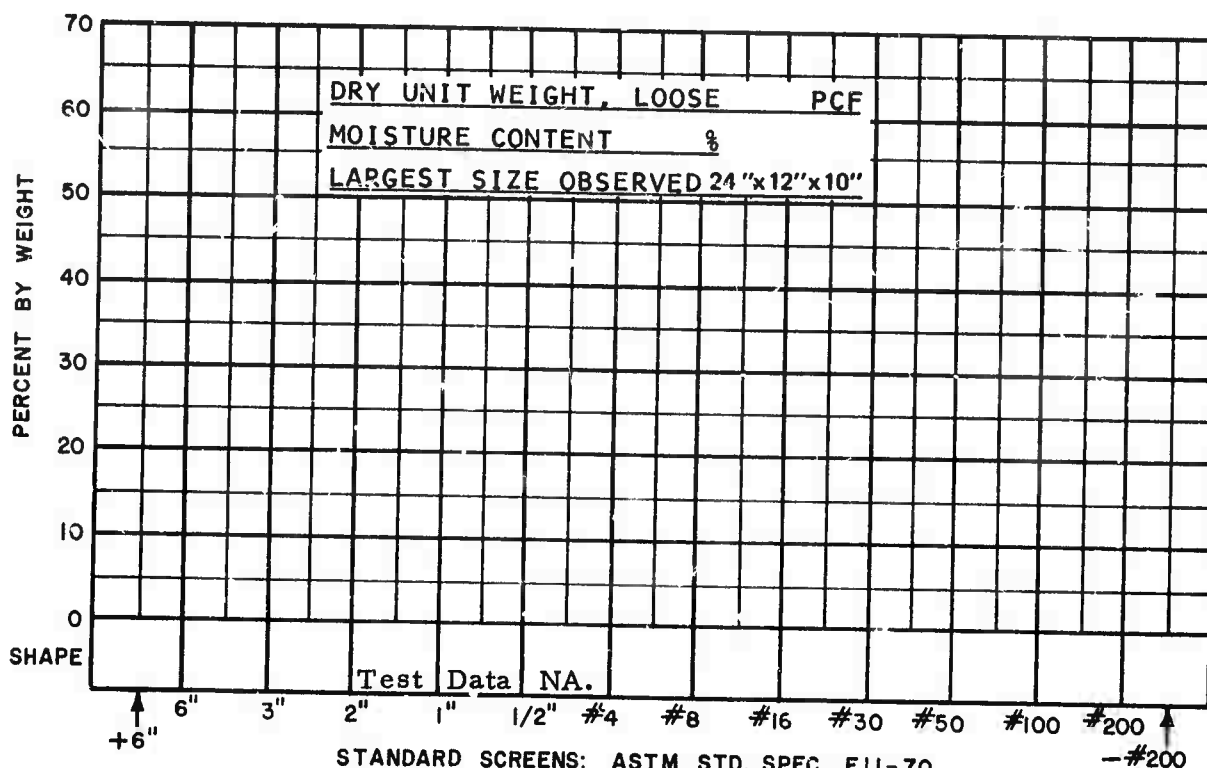
Shrinkage Limit %  
Flow Index %

MATERIAL SIZE IN.

Angle/Repose 1" Drop  
@ % Moisture,  
Angle Slide Steel Plate  
@ % Moisture,

Apparent Cohesion PSF  
@ % Moisture,  
Bulk Density PCF  
@ % Moisture,

Angle/Repose 10" Drop  
@ % Moisture,  
Angle Internal Friction  
@ % Moisture,



SUMMARY

Rock Class: Metamorphic: Hematite and martite interlayered, highly jointed, bedding normally flat, often highly folded. Low strength. RQD (Est.) 10%.

DUW: NA. Ground water: Dry. Hardness: NA.

System Class: TBM, Twin head, Alpine F-6A, 10' wide x 9'6" heading.  
68 Kennametal T. C. tipped bits. 60 RPM, 49.6 HP head torque, 20 HP sumpping thrust. Mucking: Gathering arms, flight conveyor. Haulage: Scraper to rail cars to skip. Support: Steel sets, pipe spiles.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. MB-3  
Sheet 2

### ROCK DATA:

Lithology: Metamorphic, argillaceous quartzite, medium to thin bedded, moderately to highly folded. Beds high angled to vertical, moderate fracturing sub-parallel to beds and vertical across beds.

Uniaxial Compressive Strength: NA KPSI

RQD: 75% (Estimated for vertical hole).

Dry Unit Weight: NA PCF

Ground Water: None

Hardness: NA

### TUNNEL DATA:

Size: 9' W x 10.7', 1 1/2' R. top corner arch. Grade: +1/2%

Ventilation System: 7 KCFM pressure, 24" pipe and tubing, 40 HP at 800'.

Utility System: 4" air line, 2" water line.

Water Inflow: None to minor.

Power System: 2300/480/120 (lighting).

Haulage System: Muck, personnel, supplies by rail cars, 24" gage, 40# rail, 6 ton battery locomotive, 60 CF side dump cars.

Support System: 9' x 13" mats, parallel to centerline, 2 in top and 2 each rib, 4 3/4" x 6' rock bolts per mat.

### EXCAVATION DATA:

Conventional Rail System.

Drilling: 3 boom jumbo, 2-S83F and 1-D99 machines, 8' screw feeds.

Drill Round: 44 holes: 2-4" and 42-1 5/8" diameter, burn cut, 7' depth.

Explosives: 100# Nilite, 25#-60 WR 1" x 16" primers.

Blasting: Electrical, zero and 14 regular delays. Powder Factor: 5.4#/CY.

Mucking System: Atlas-Copco LM56 overhead.

Guidance: Transit lines.

MUCK DATA      Test Data NA.

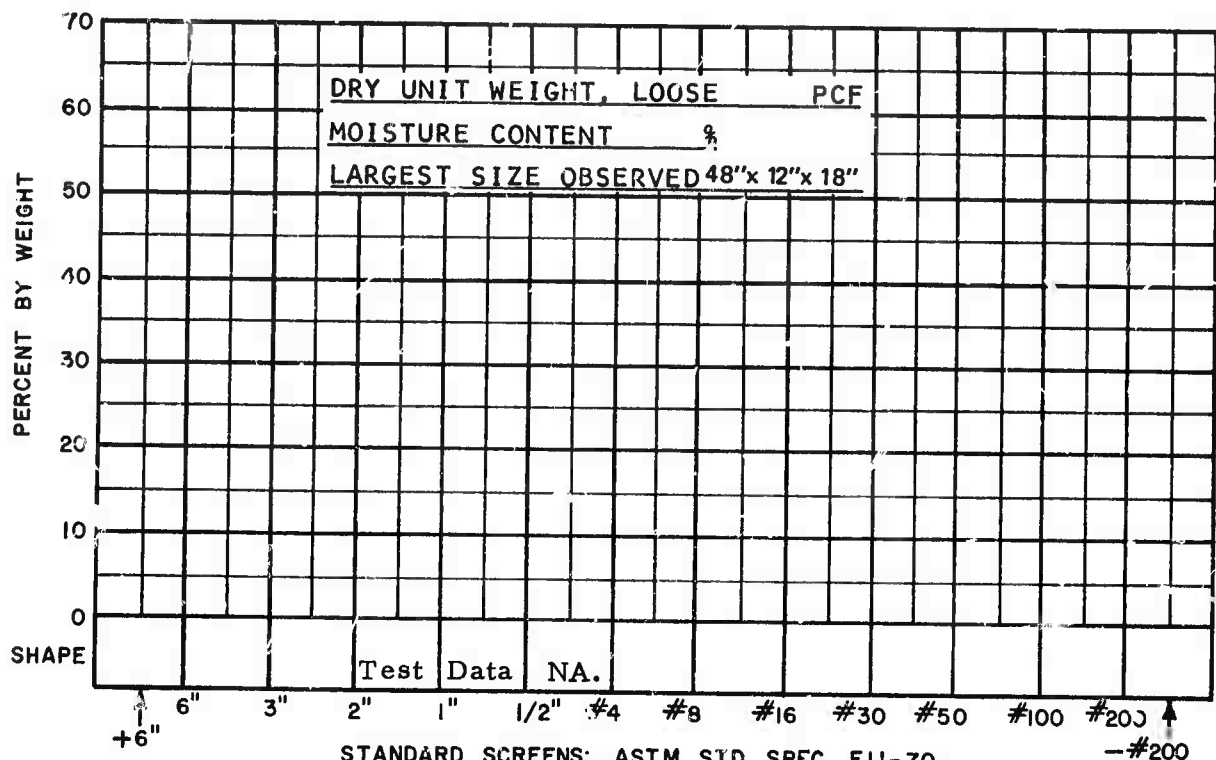
Abrasiveness                      Pot. Vol. Change, Material                      Spec. Gravity, Material  
N. A.                                  Size                                  :                                  Size                                  :

ATTERBERG LIMITS, MATERIAL SIZE                      IN.

Liquid Limit                      %                      Plastic Limit                      %                      Shrinkage Limit                      %  
Plasticity Index                      %                      Toughness Index                      %                      Flow Index                      %

MATERIAL SIZE                      IN.

Angle/Repose 1" Drop                      Apparent Cohesion PSF                      Angle/Repose 10" Drop  
@                      % Moisture,                      @                      % Moisture,                      @                      % Moisture,  
Angle Slide Steel Plate                      Bulk Density PCF                      Angle Internal Friction  
@                      % Moisture,                      @                      % Moisture,                      @                      % Moisture,



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Argillaceous quartzite, moderately fractured, moderately to highly folded, medium to thin bedded. Strength: NA.  
RQD (Est.) 75%. DUW: NA. Ground water: None. Hardness: NA.

System Class: Conventional Rail: 9' x 10'7", 3 boom jumbo, 44-7' holes, burn cut. PF 5.4 #/CY. Mucking: Atlas Copco LM56. Haulage: Rail.  
Support: Rockbolts and mats.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. ST-1  
Sheet 2

### ROCK DATA:

Lithology: Metamorphic, quartzite, with minor filled veinlets, thin bedded to massive, moderately folded, moderately to highly fractured/jointed, beds dip 75°-90°.

Uniaxial Compressive Strength: NA

RQD: (Estimated) Vertical: 50%, horizontal 20-30%.

Dry Unit Weight: NA

Ground Water: Minor

Hardness: NA

### TUNNEL DATA:

Size: 10' x 10' with 1 1/2' top corner radius. Grade: (+) 0.5%.

Ventilation: 13.5 KCFM, pressure, 24" diameter pipe, 80 HP @ 1700' from cooling unit.

Utility System: 4" air line, 2" water line, 2" pumpline.

Power System: 2300/480/120.

Haulage System: Muck, Eimco 912B-LHD to skip pocket, skips and rail to surface.

Personnel, Supplies: Rail, cage to level, LHD or Jumbo on level.

Support System: 13" x 9' plates, 5' x 5/8" rock bolts at 3 1/2', plates and rock bolts on ribs where needed.

### EXCAVATION DATA:

Conventional Trackless System.

Drilling: 2 boom hydrojib jumbo, 8' feed, D-93 drifters.

Drill Round: 48 holes, 1 5/8" diameter x 8' V cut.

Explosives: 265#, 250# Nilite, 15# Trojan 60 WR. Powder factor, 9.5#/CY.

Blasting: Electrical, Dupont Acudet 0-14 delay caps.

Mucking: Eimco 912B-LHD.

Guidance: Laser



MUCK DATA    Test Data NA.

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size :

Spec. Gravity, Material  
Size :

ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit        %  
Plasticity Index        %

Plastic Limit        %  
Toughness Index        %

Shrinkage Limit        %  
Flow Index        %

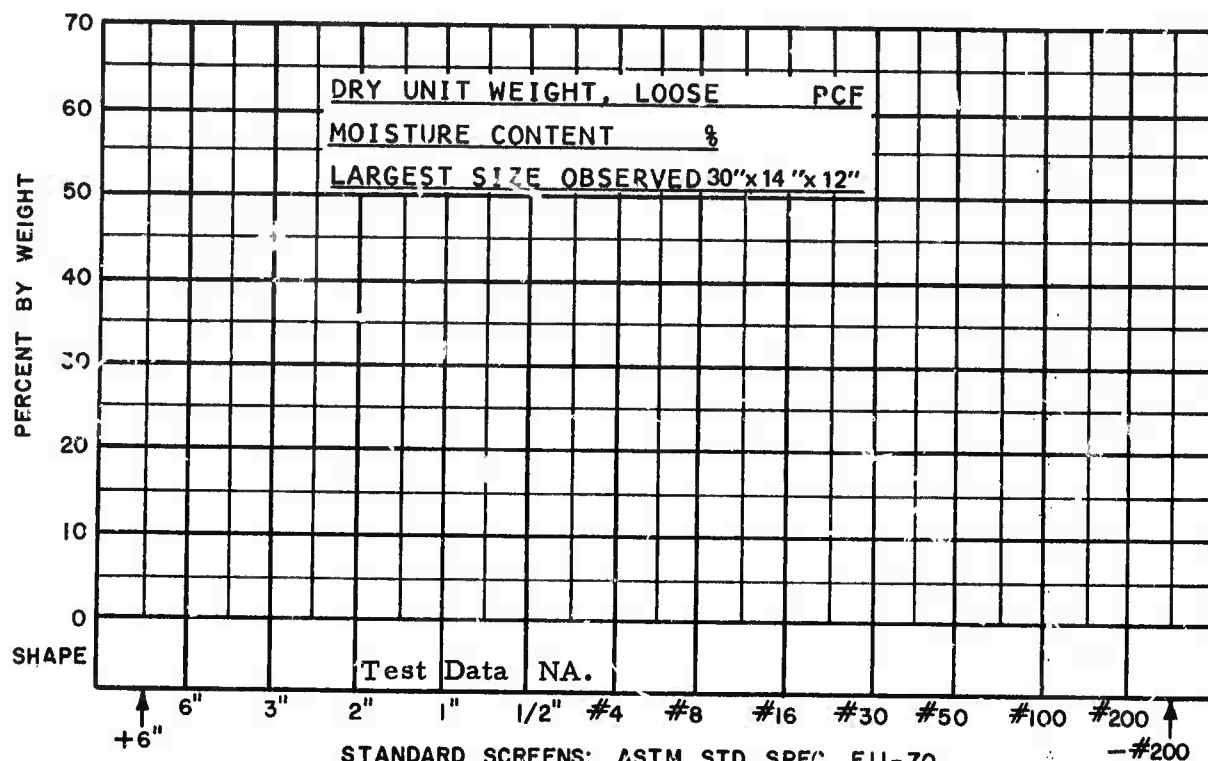
MATERIAL SIZE

IN.

Angle/Repose 1" Drop  
@        % Moisture,  
Angle Slide Steel Plate  
@        % Moisture,

Apparent Cohesion PSF  
@        % Moisture,  
Bulk Density PCF  
@        % Moisture,

Angle/Repose 10" Drop  
@        % Moisture,  
Angle Internal Friction  
@        % Moisture,



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Quartzite minor filled veinlets, moderately to highly fractured/jointed, moderately folded, beds dip 75° to 90°. Strength: NA. RQD (Est.) 50%. DUW: NA. Hardness: NA.

System Class: Conventional Trackless: 10' x 10', 2 boom jumbo, 48-8' holes, V cut. PF 9.5 #/CY. Mucking: Eimco 912B. Haulage: LHD. Support: Rock bolts and plates.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. CR-1  
Sheet 2

### ROCK DATA:

Lithology: Metamorphic, phyllite, with vein quartz and chlorite schist, highly metamorphosed and folded, with minor faulting.

Uniaxial Compressive Strength: 19 KPSI

RQD: (Estimated) 70%

Dry Unit Weight: 187 PCF

Ground Water: Dry

Hardness: NA

### TUNNEL DATA:

Size: 7'-6" wide x 8'-6" arch.

Ventilation: 7 KCFM, 16" diameter pipe, 30 HP @ 300'. Fan integral with mechanical cooling unit.

Utility System: 2" water line, 2" airline, 4" water line to cooling unit.

Water Inflow: Minor

Power System: 2400/440/110V.

Haulage System: Muck, supplies, personnel by railcars, 6 and 8 ton locomotives 1 1/2 ton rocker dump cars, 18" gage, 40# rail car passes 80'-300' from face.

Support System: Normally none, 5/8" x 6' rock bolts as required.

### EXCAVATION DATA:

Conventional Rail System

Drilling: 2-6' feed air legs, mounting 3" jackhammers.

Drill Round: 34 holes, 5-2" diameter burncut, circular or box relievers 29 x 1 1/4", average advance 10' per round.

Explosives: 140#, 131# AN/FO, 9#-1 x 6", 60% primers.

Blasting: Electrical, 7 millisecond delays, 10 regular delays.

Powder factor, 7.0#/CY.

Mucking: Eimco, model 21.

Guidance: Transit survey.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. HS-1  
Sheet 1

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-)0.056" : 0

Spec. Gravity, Material  
Size (-)0.75" : 2.84

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.80%

Plastic Limit 16.06 %

Shrinkage Limit 15.12 %

Plasticity Index 2.74 %

Toughness Index 1.01 %

Flow Index 2.70 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 3.1 % Moisture, 40°

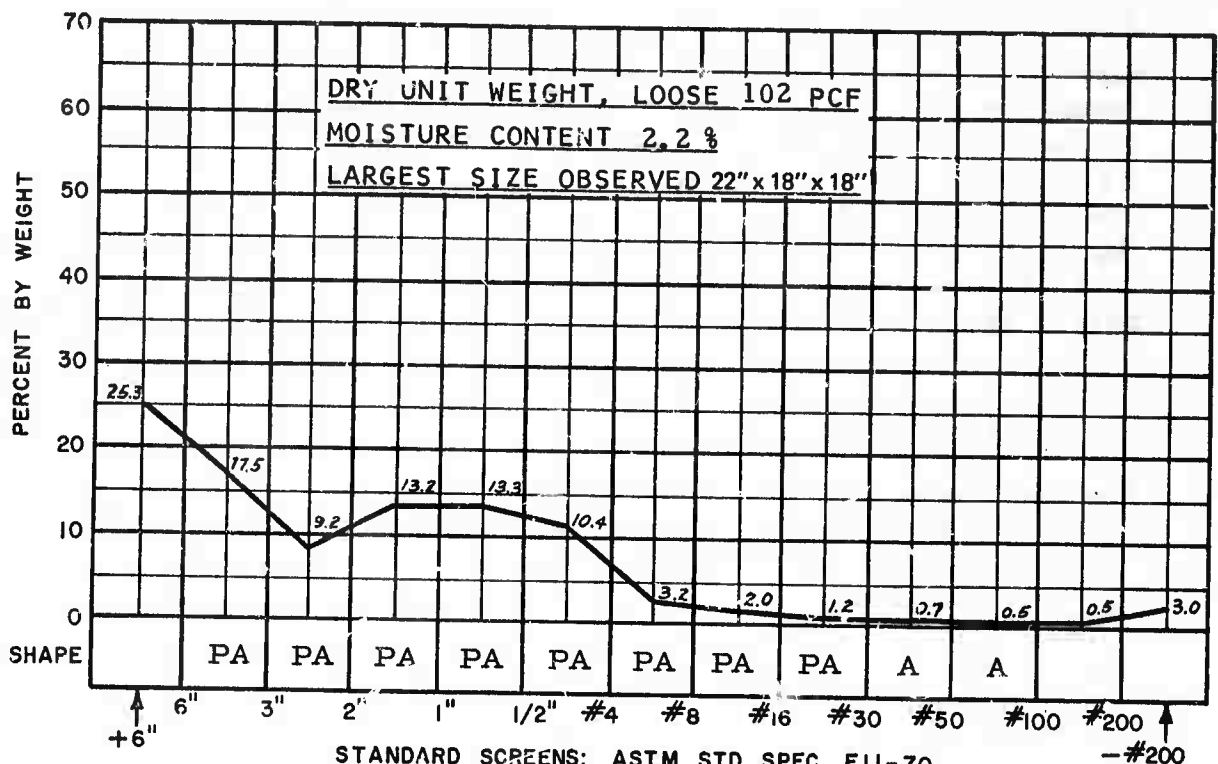
Apparent Cohesion PSF  
@ 2.0 % Moisture, 160

Angle/Repose 10" Drop  
@ 3.1 % Moisture, 34°

Angle Slide Steel Plate  
@ 3.1 % Moisture, 31°

Bulk Density PCF  
@ 0.0 % Moisture, 99

Angle Internal Friction  
@ 2.0 % Moisture, 39°



DRY UNIT WEIGHT, LOOSE 102 PCF  
MOISTURE CONTENT 2.2 %  
LARGEST SIZE OBSERVED 22"x18"x18"

STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Metamorphic: Phyllite with vein quartz and chlorite schist, highly metamorphosed and folded. High strength. RQD (Est.) 70%.  
DUW: 187 PCF. Ground water: Dry. Hardness: NA.

System Class: Conventional Rail. 7' 6" wide x 8' 6" arch, two air leg drills, 34-10' holes, burn cut. PF 7.0 #/CY. Mucking: Eimco 21. Haulage: Rail. Support: None.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. HS-1  
Sheet 2

ROCK DATA:

Lithology: Metamorphic, mica schist. occasional quartz laminations.  
Uniaxial Compressive Strength: NA  
RQD: (Estimated) 80%.  
Dry Unit Weight: NA  
Ground Water: Dry  
Hardness: NA

TUNNEL DATA:

Size: 11'-6" diameter. Grade: (-) 0.03%.  
Ventilation: 3.6 KCFM, exhaust, @ 3475', 20" diameter pipe, 40 HP.  
Utility System: 4" airline, 4" waterline, 6" pumpline.  
Water Inflow: 40 GPM  
Power System: 6600V/440V.  
Haulage System: Muck, supplies, personnel by railcars, 10 ton locomotive  
17 CY cars, 36" gage, 70# rail.  
Support System: Half circle bolted steel lagging in fault zones, pinned to ribs.

EXCAVATION DATA:

Machine: Jarva, 12-1100, Total Weight: NA.  
Cutters: 30 Reed steel disc and 6 Jarva TCB disc. Gage: 6 TCB QKC-3W.  
2 disc. Interior: 28 steel 3 disc QK3. Center: 2 steel 5 disc QK-1.  
Rotation: NA RPM.  
Torque: NA.  
Thrust: NA.  
Muck Collection: Buckets from face, belt to rear.  
Power System: NA.  
Guidance: Laser.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size : NA

Spec. Gravity, Material  
Size : NA

## ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %

Plastic Limit NA %

Shrinkage Limit NA %

Plasticity Index NA %

Toughness Index NA %

Flow Index NA %

## MATERIAL SIZE

IN.

Angle/Repose 1" Drop  
@ % Moisture, NA

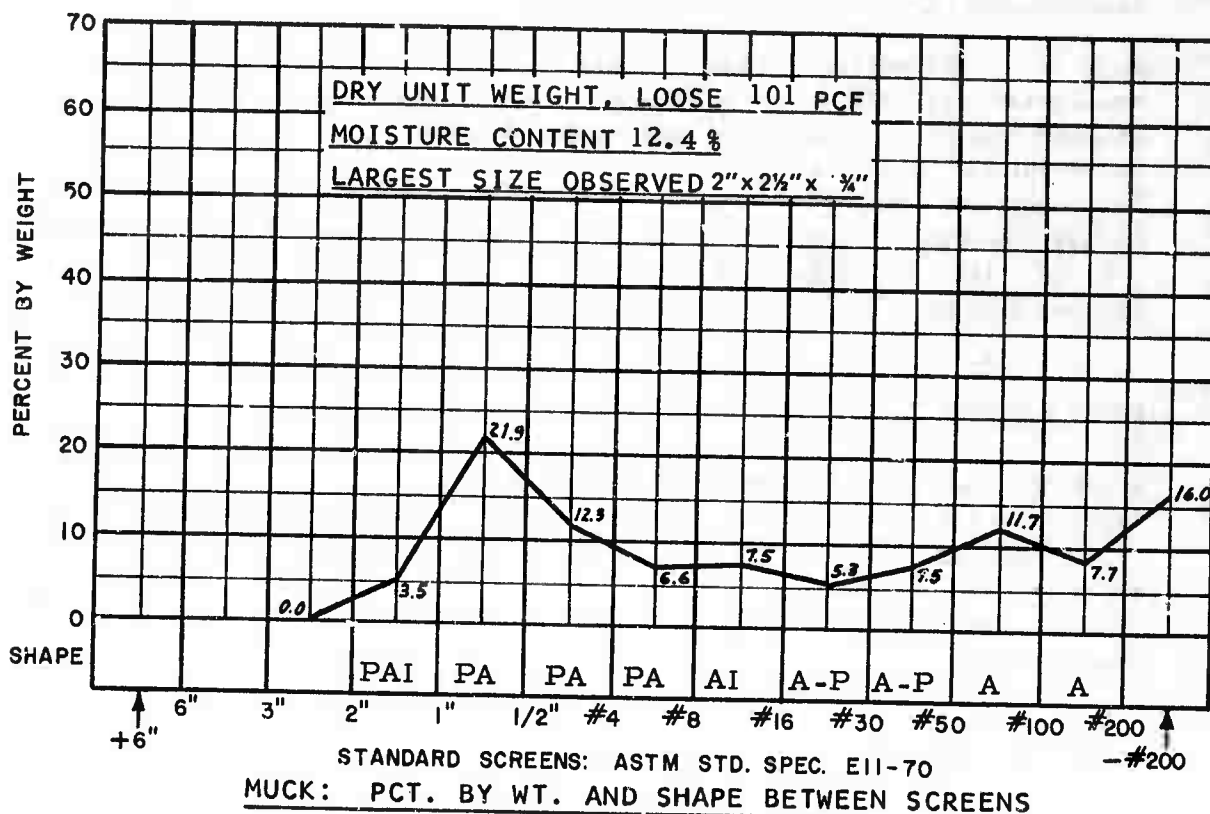
Apparent Cohesion PSF  
@ % Moisture, NA

Angle/Repose 10" Drop  
@ % Moisture, NA

Angle Slide Steel Plate  
@ % Moisture, NA

Bulk Density PCF  
@ % Moisture, NA

Angle Internal Friction  
@ % Moisture, NA



## SUMMARY

Rock Class: Metamorphic: Mica schist, occasional quartz lamination.  
Strength: NA. RQD (Est.) 80%. DUW: NA. Ground water: Dry.  
Hardness: NA.

System Class: TBM, Jarva 12-1100, 11'6" dia. 30 Reed and 6 Jarva discs. RPM: NA, Torque: NA, Thrust: NA. Mucking: Buckets to belt. Support: None.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. NY-1  
Sheet 2

ROCK DATA:

Lithology: Metamorphic, mica schist, occasional quartz laminations.  
Uniaxial Compressive Strength: NA.  
RQD: (Estimated) 90%.  
Dry Unit Weight: NA.  
Ground Water: Dry  
Hardness: NA.

TUNNEL DATA:

Size: 8'-6" diameter. Grade: (+) 0.03%.  
Ventilation: 18 KCFM, exhaust @ 1500', 12" diameter pipe, 40 HP  
Utility System: 4" airline, 4" waterline, 4" pumpline.  
Water Inflow: 20 GPM.  
Power System: 6600/440V.  
Haulage System: Muck, supplies, personnel by railcars 10 ton locomotive  
13 CY cars, 36" gage, 70# rail.  
Support System: Half circle bolted steel lagging in fault zones, pinned to ribs.

EXCAVATION DATA:

Machine: Jarva 8-806. Total Weight: NA.  
Cutters: 14 Reed disc and 3 Jarva TCB disc. Gage 3 TCB disc QKC-3W  
Interior, 12 TCB disc QC-3, center 2 steel tooth type.  
Rotation: NA RPM.  
Torque: NA.  
Thrust: NA.  
Muck Collection: Buckets from face, belt to rear.  
Power System: NA.  
Guidance: Laser.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size : NA

Spec. Gravity, Material  
Size : NA

## ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %

Plastic Limit NA %

Shrinkage Limit NA %

Plasticity Index NA %

Toughness Index NA %

Flow Index NA %

## MATERIAL SIZE

IN.

Angle/Repose 1" Drop  
@ % Moisture, NA

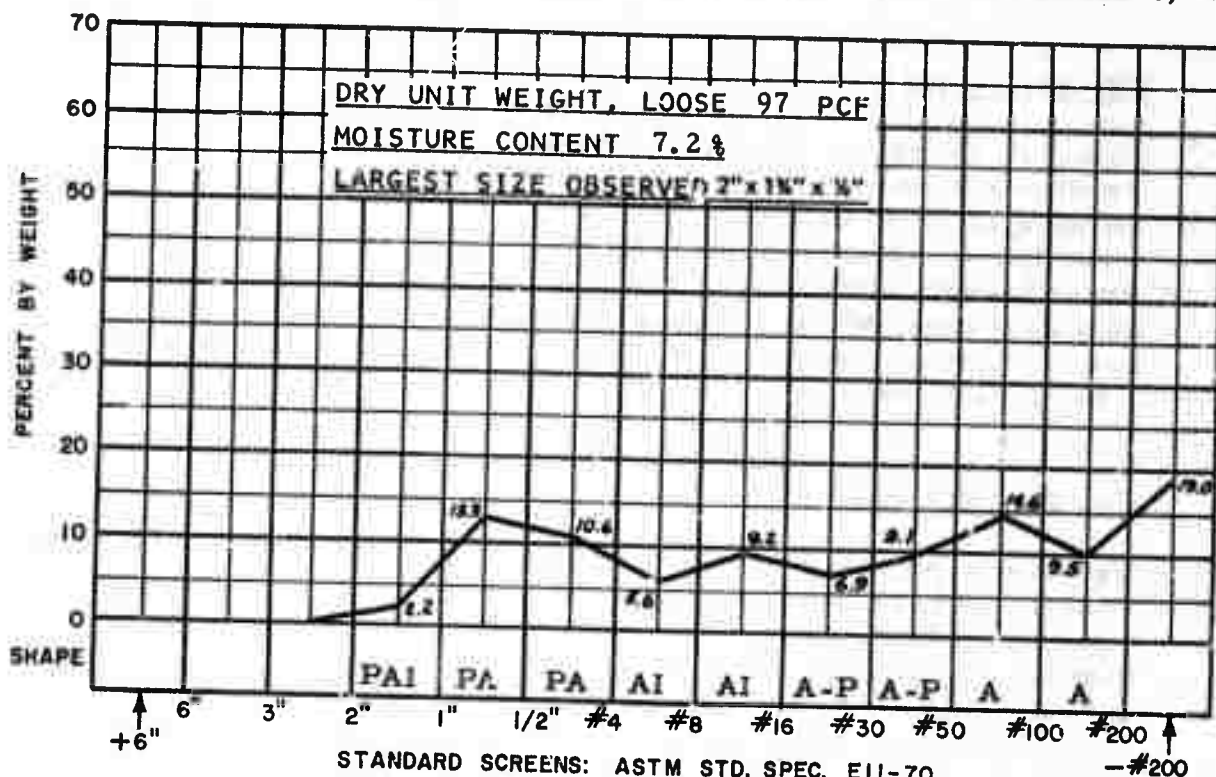
Apparent Cohesion PSF  
@ % Moisture, NA

Angle/Repose 10" Drop  
@ % Moisture, NA

Angle Slide Steel Plate  
@ % Moisture, NA

Bulk Density PCF  
@ % Moisture, NA

Angle Internal Friction  
@ % Moisture, NA



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Metamorphic: Mica schist, occasional quartz laminations.  
Strength: NA. RQD (Est.) 90%. DU<sub>w</sub>: NA. Ground water: Dry.  
Hardness: NA.

System Class: TBM, Jarva 8-806, 8'6" dia. 14 Reed and 3 Jarva discs and rollers. RPM: NA. Torque: NA. Thrust: NA. Mucking: Buckets to belt.  
Haulage: Rail. Support: None.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. NY-2  
Sheet 2

#### ROCK DATA:

Lithology: Metamorphic, gray mica schist, occasional quartz seams, mica varies from dense fine grained to extremely coarse.

Uniaxial Compressive Strength: 11 KPSI.

RQD: (Estimated) 30%

Dry Unit Weight: 165 PCF

Ground Water: Major inflow occurs in faults and fault zones.

Hardness: NA

#### TUNNEL DATA:

Size: 11', diameter. Grade: (+) 1 to 3%

Ventilation System: 4 KCFM exhaust 14" pipe.

Utility System: 4" waterpipe, no airline.

Water Inflow: 60 gpm, drains in ditch

Power System: 4160/480V

Haulage System: Muck, personnel, supplies by rail cars.

Support System: None, occasional semi-circular plates pinned at spring line in fault zones

#### EXCAVATION DATA:

Machine: Jarva, Mark 11-1100, Total Weight: 70 tons

Cutters: 34 Reed, type QK steel multiple disc. Gage: 6 triple disc.

Center: 2-triple disc. Interior: 26 triple disc.

Rotation: Cutterhead, 10.75 RPM

Torque: 244 K ft. #

Anchor Pressure: Maximum 3,402 K#.

Thrust: 1,134 K#. operating

Muck System: Buckets from face, belt to rear.

Power System: Four 125 HP, 480V motors drive head, 40 HP 480V motor drive hydraulic system.

Guidance System: Laser



# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056" : 0

Spec. Gravity, Material  
Size (-) 0.75" : 2.57

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 24.0 %

Plastic Limit 23.3 %

Shrinkage Limit 22.7 %

Plasticity Index 0.7 %

Toughness Index 0.17 %

Flow Index 4.0 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 9.8 % Moisture, 39°

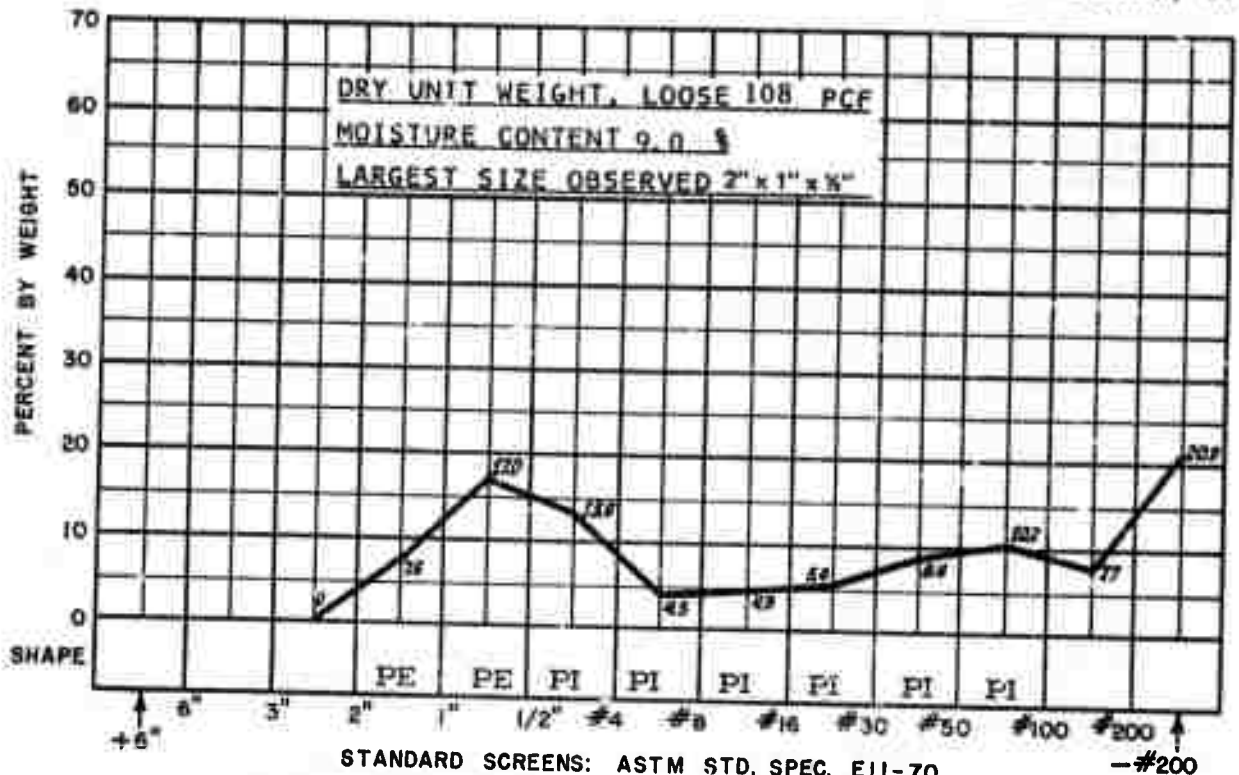
Apparent Cohesion PSF  
@ 9.3 % Moisture, 125

Angle/Repose 10" Drop  
@ 9.8 % Moisture, 37°

Angle Slide Steel Plate  
@ 8.4 % Moisture, 40°

Bulk Density PCF  
@ 0.0 % Moisture, 75

Angle Internal Friction  
@ 9.3 % Moisture, 30°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Metamorphic: Mica schist, dense, fine grained to extremely coarse occasional quartz seams. Medium strength. RQD (Est.) 30%.  
DUW: 165 PCF. Ground water: Minor inflows at fault zones. Hardness: NA.

System Class: TBM, Jarva Mark 11-1100, 11' dia. 36 Reed triple discs.  
RPM: 10.75. Torque: 244 K ft #. Thrust: 1,134 K #. Mucking: Buckets to belt. Haulage: Rail. Support: Minor, semicircular plates in fault zones.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. QL-1  
Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, graywacke ("argillaceous quartzite"), massive to medium bedded, highly folded and fractured, normal dip of bedding 30° to 45°.

Uniaxial Compressive Strength: NA.

RQD: (Estimated) 35%.

Dry Unit Weight: NA.

Ground Water: None.

Hardness: NA.

#### TUNNEL DATA:

Size: 10' wide x 10.8'. Grade: (+) 2%.

Ventilation System: 8 KCFM, exhaust, 16" diameter pipe, 30 HP @ 1800' and pressure auxiliary, 8" pipe, 5 HP @ 100'.

Utility System: 6" air line, 4" water line.

Water Inflow: None.

Power System: 2300/480/120V.

Haulage System: Muck, personnel, supplies by railcars, 30" gage, 80# and 60# rail, 10 ton trolley locomotives, 200 and 140 C<sub>r</sub> bottom dump cars to skip pocket, 14 ton skips to surface.

Support System: Roof plates and 3/4" x 6' bolts as required.

#### EXCAVATION DATA:

Conventional Rail System.

Drilling: Hydrojib jumbo, 2 boom, D93 drifters, 1 1/4" round steel on 10' chain feeds.

Drill Round: 36 holes, 1 5/8" diameter, V cut, 8' depth.

Explosives: 210#, 200# Aramonium Nitrate, 10#-7/8" x 8", 70% in ribs and top. Powder factor, 7.5#/CY.

Blasting: Detaprime primers, caps, fuse and igniter cord.

Mucking System: Eimco Model 40 mucker.

Guidance: Transit Lines.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. MB-2  
Sheet 1

# MUCK DATA

Test Data NA.

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size :

Spec. Gravity, Material  
Size :

## ATTERBERG LIMITS, MATERIAL SIZE

IN.

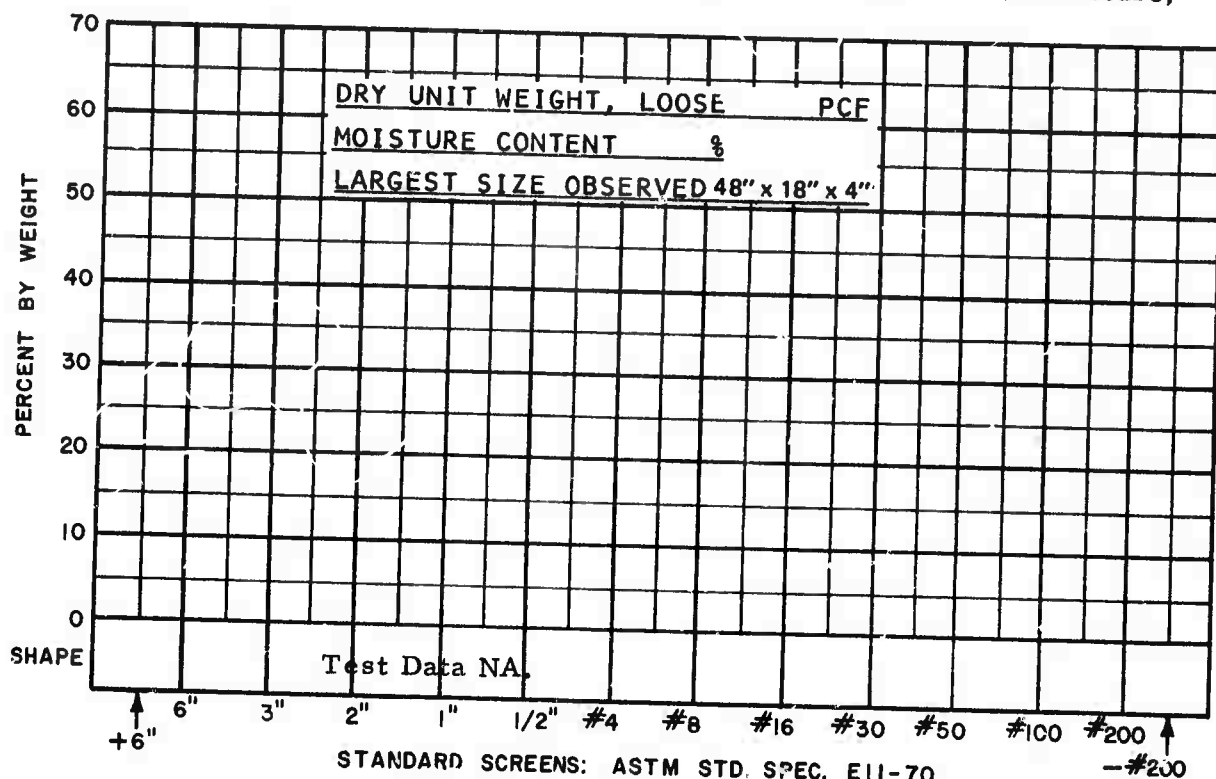
Liquid Limit	%	Plastic Limit	%	Shrinkage Limit	%
Plasticity Index	%	Toughness Index	%	Flow Index	%

MATERIAL SIZE IN.

Angle/Repose 1" Drop  
@ % Moisture,  
Angle Slide Steel Plate  
@ % Moisture,

Apparent Cohesion PSF  
@ % Moisture,  
Bulk Density PCF  
@ % Moisture,

Angle/Repose 10" Drop  
@ % Moisture,  
Angle Internal Friction  
@ % Moisture,



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Graywacke, massive to medium bedded, normal dip 30° to 45°, highly folded and fractured. NA strength. RQD (Est.) 35%.  
DUW: NA PCF. Ground water: None. Hardness: NA.

System Class: Conventional rail, 10' wide x 10.8'. Two machine jumbo, 36 - 8' holes, V cut. PF 7.5 #/CY. Overhead loader mucking - rail haulage.  
Support: Rock bolts and plates as required.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. MB-2  
Sheet 2

#### ROCK DATA:

Lithology. Sedimentary, sandstone, fine grained, well compacted light brown, over 50 percent quartz.  
Uniaxial Compressive Strength: 22 KPSI.  
RQD: 92%.  
Dry Unit Weight: 166 PCF  
Ground Water: Dry.  
Hardness: Shore 61.

#### TUNNEL DATA:

Size: 18'-1" dia. Grade (-) 7%  
Ventilation System: 17 K CFM, exhaust, 36" dia. pipe, 75 HP @ 4100'.  
Utility System: 2" water line, 4" pump line. No air line - compressor on machine.  
Water Inflow: 5-10 gpm  
Power System: 4160/480V  
Haulage System, Muck: 390' of 30" "piggy back" conveyor supported by a monorail advances with the TBM, discharges on a 36" conveyor suspended from the back of the tunnel. Supply and Personnel: Diesel jeeps and trucks.  
Support System: 6" x 8.2# channels x 9.5' or 13.5' @ 4' or 2', secured by 4-5/8" x 4' rock bolts. Channels also support monorail.

#### EXCAVATION DATA:

Machine: Robbins 181-122 Weight: 260 tons.  
Cutters: 47 Robbins, Steel Disc. Gage: 3-12". Center: 1-7 1/2" triple, Interior: 43-12".  
Rotation: 4 1/2 RPM (Center integral with head)  
Torque: 1,720 K ft. #  
Thrust: 1,580 K# max., 914 K# operating.  
Muck Collection: Buckets fixed to head, discharging on a 30" conveyor.  
Power System: Six-480V., 200 HP motors drive head. Hydraulic pumps power thrust and anchor cylinders.  
Guidance System: Laser.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. 5-1  
Sheet 1

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.065": 0

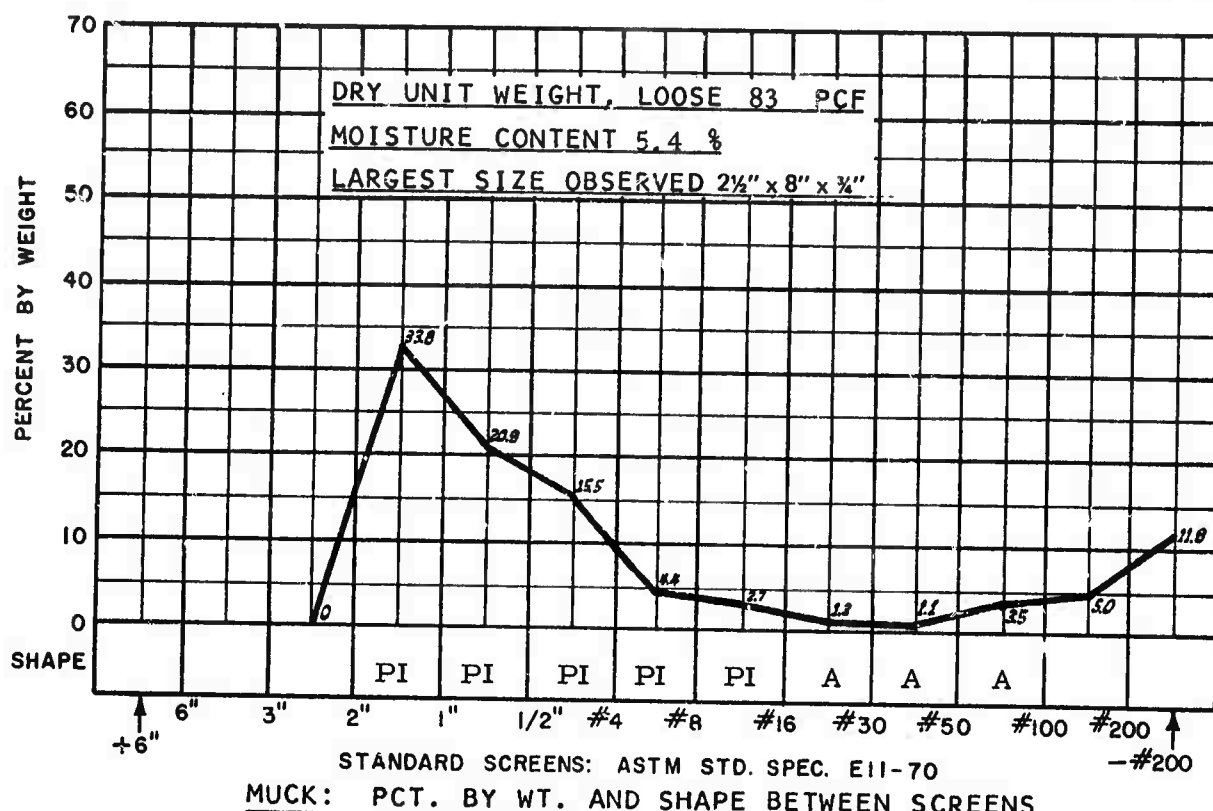
Spec. Gravity, Material  
Size (-) 0.75": 2.73

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.185 IN.

Liquid Limit 16.90% Plastic Limit 15.50% Shrinkage Limit 15.18%  
Plasticity Index 1.40% Toughness Index 0.28% Flow Index 5.0%

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop Apparent Cohesion PSF Angle/Repose 10" Drop  
@ 6.3 % Moisture, 35° @ % Moisture, NA @ 6.3 % Moisture, 29°  
Angle Slide Steel Plate Bulk Density PCF Angle Internal Friction  
@ 6.3 % Moisture, 28° @ % Moisture, NA @ 4.8 % Moisture, 29°



## SUMMARY

Rock Class: Sedimentary: Sandstone, fine grained, well compacted, over 50% quartz. High strength. RQD: 92%. DUW: 171 PCF. Ground water: Dry. Hardness: Shore 61.

System Class: TBM, Robbins 181-122, 18' 1" dia. 47 Robbins disc cutters. RPM: 4-1/2, 1,720 K FT. # torque, 914 K# thrust. Mucking: Buckets to belt conveyor. Haulage: Traveling conveyor - suspended conveyor - skip to surface. Support: Channels and rock bolts at 4' or 2', continuous.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. 5-1  
Sheet 2

### ROCK DATA:

Lithology: Sedimentary, sandstone, fine grained, well compacted light brown, over 50 percent quartz.

Uniaxial Compressive Strength: 22 KPSI.

RQD: 92%.

Dry Unit Weight: 166 PCF.

Ground Water: Dry.

Hardness: Shore 61.

### TUNNEL DATA:

Size: 18'-1" dia. Grade (+) 2%.

Ventilation System: 17 K CFM, exhaust, 36" dia. pipe, 75 HP @ 4800'.

Utility System: 2" water line, 4" pump line. No air line - compressor on machine.

Water Inflow: 5-10 gpm.

Power System: 4160/480V.

Haulage System, Muck: 390' of 30" "piggy back" conveyor supported by a monorail advances with the TBM, discharges on a 36" conveyor suspended from the back of the tunnel. Supply and Personnel: Diesel jeeps and trucks.

Support System: 6" x 8.2# channels x 9.5' or 13.5' @ 4' or 2', secured by 4-5/8" x 4' rock bolts. Channels also support monorail.

### EXCAVATION DATA:

Machine: Robbins 181-122 Weight: 260 tons.

Cutters: 47 Robbins, Steel Disc. Gage: 3-12". Center: 1-7 1/2" triple, Interior: 43-12".

Rotation: 4 1/2 RPM (Center integral with head)

Torque: 1,720 Kft #

Thrust 1,580 K# max., 747 K# operating.

Muck Collection: Buckets fixed to head, discharging on a 30" conveyor.

Power System: Four-480V., 200 HP motors drive head. Hydraulic pumps power thrust and anchor cylinders.

Guidance System: Laser.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056" : 0

Spec. Gravity, Material  
Size (-) 0.75" : 2.63

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 23.0 %

Plastic Limit 17.63 %

Shrinkage Limit 17.58 %

Plasticity Index 5.37 %

Toughness Index 0.78 %

Flow Index 6.90 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 2.6 % Moisture, 32°

@ 2.8 % Moisture, 0

@ 2.6 % Moisture, 31°

Angle Slide Steel Plate

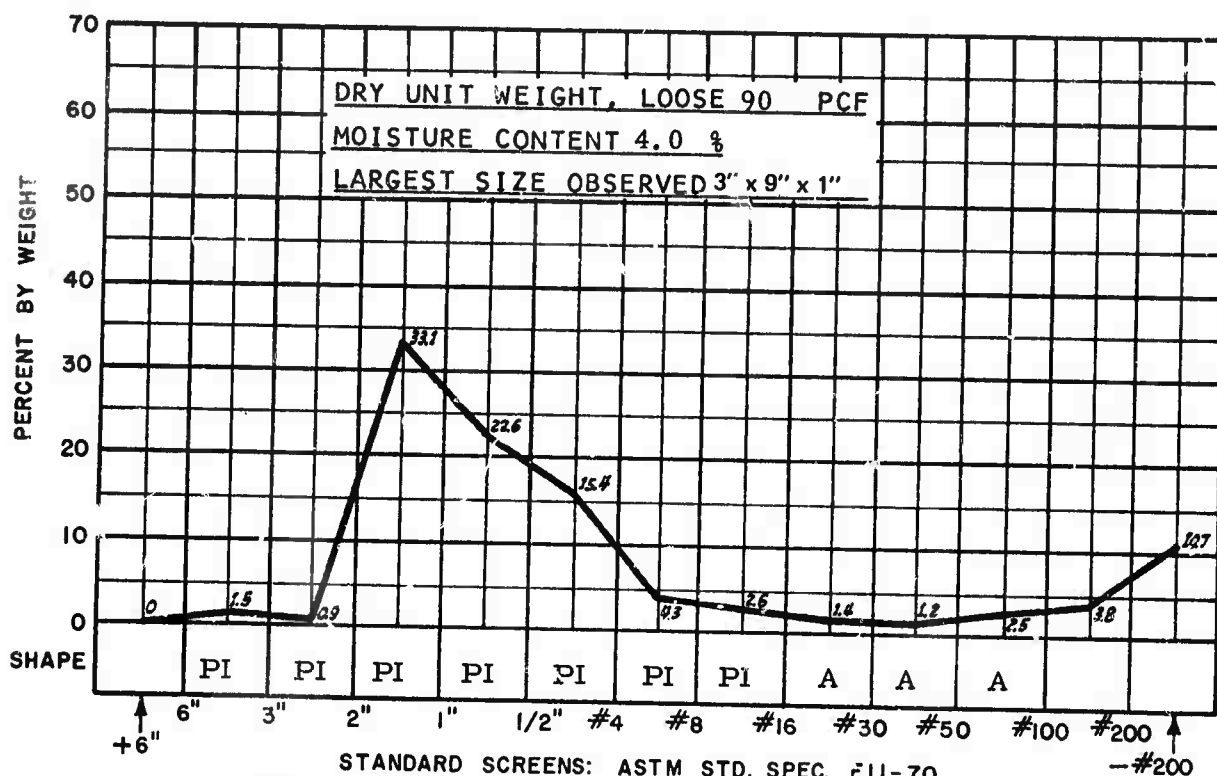
Bulk Density PCF

Angle Internal Friction

@ 2.6 % Moisture, 29°

@ 0.0 % Moisture, 92.8

@ 2.8 % Moisture, 44°



## SUMMARY

Rock Class: Sedimentary: Sandston, fine grained, well compacted, over 50% quartz. High strength. RQD: 92%. DUW: 171 PCF. Ground water: Dry. Hardness: Shore 61.

System Class: TBM, Robbins 181-122, 18'1" dia. 47 Robbins disc cutters. 4-1/2 RPM, 1,720 K FT # torque, 747 K# thrust. Mucking: Buckets to belt conveyor.

Haulage: Traveling conveyor - suspended conveyor - skip to surface.

Support: Channels and rock bolts at 4' or 2', continuous.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. 7-2  
Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, "shale", massive to thinly-laminated, interbedded siltstone and shale, with minor sandstone and limestone layers. Grain size varies from fine to coarse, quartz content from 24 to 33%.

Uniaxial Compressive Strength: Four major beds: 22 K to 29 KPSI, three minor beds: 12 K to 17 KPSI. Weighted Average: 23 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 152 PCF.

Ground Water: Dry

Hardness: Shore 41 to 55 parallel to bedding planes, 41 to 54 perpendicular.

#### TUNNEL DATA:

Size: 24' wide x 7 1/2' rectangular. Grade: Varies

Ventilation System: 80-100K CFM, pressure

Utility System: 4" air, 4" water, 4" pump, where required.

Water Inflow: Normally none.

Power System: 110V. lighting-all equipment diesel or air powered.

Haulage System: Wagner ST-5 Scooptrams, 16 ton shuttle cars to conveyors, 1 1/2 CY loaders for cleanup. Personnel and supplies, diesel jeeps and trucks.

Support System: 5/8" x 6' rock bolts on 4' x 4' pattern, 11" wide x 10' roof plates where required.

#### EXCAVATION DATA:

Conventional Trackless System.

Drilling: Two boom hydrojib jumbos, AR93 drifters, 14' feed.

Drill Round: 35 holes, 1 3/4" diameter, 10 1/2 to 11' deep, and 1-6' buster hole, V-cut.

Explosives: 16# -1 1/4" x 8", 75% primers, 32# -1 1/4" x 12" RXL, 60% in lifters, 11# coalite 5Y, 1 1/4" x 12" in back holes, 175# AN/FO in remainder of round. Powder factor: 3.5#/CY.

Blasting: Electrical, MS delays.

Mucking: Wagner ST-5 Scooptrams.

Guidance: Transit/Laser.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. 11-3

Sheet 1



# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056" : 0

Spec. Gravity, Material  
Size (-) 0.75" : 2.65

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.60 %

Plastic Limit 14.81 %

Shrinkage Limit 14.51 %

Plasticity Index 0.79 %

Toughness Index 0.26 %

Flow Index 3.00 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 1 % Moisture, 25°

@ 0.2 % Moisture, 550

@ 1 % Moisture, 25°

Angle Slide Steel Plate

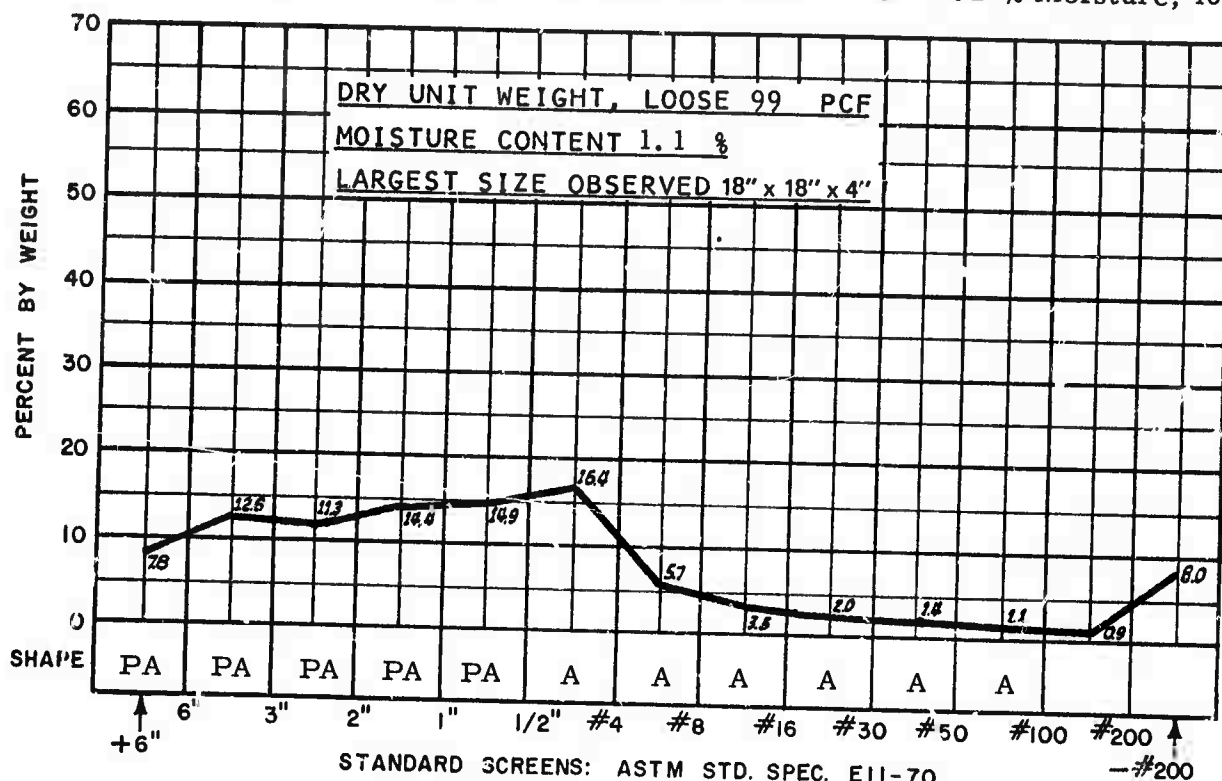
Bulk Density PCF

Angle Internal Friction

@ 1 % Moisture, 29°

@ 0.0 % Moisture, 100

@ 0.2 % Moisture, 46°



STANDARD 3 SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Shale and siltstone, minor sandstone and limestone, thin to massive, fine to coarse grained. High strength. RQD (Est.) 90%.  
DUW: 152 PCF. Ground water: Dry. Hardness: Shore, 41-55.

System Class: Conventional trackless. 24' wide x 7-1/2', rectangular. Two boom jumbo, 35-1-3/4" holes, V-cut. PF 3.5#/CY. Mucking: Scooptram. Haulage: Scooptram and/or shuttle cars to conveyor. Support: Rock bolts, 4' x 4' pattern.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. 11-3

Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, "shale", massive to thinly laminated, interbedded siltstone and shale, with minor sandstone and limestone layers. Grain size varies from fine to coarse, quartz content from 24 to 33%.

Uniaxial Compressive Strength: Four major beds: 22 K to 29 KPSI, three minor beds: 12 K to 17 KPSI. Weighted Average: 22 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 166 PCF.

Ground Water: Dry.

Hardness: Shore 41.0 to 55 parallel to bedding planes, 41 to 54 perpendicular.

#### TUNNEL DATA:

Size: 18' wide x 8 1/2' high, rectangular. Grade: Level.

Ventilation System: 20 KCFM exhaust from face, pressure to entry, 40 HP.

Utility System: 2" water line (250 cfm compressor on machine trailer).

Water Inflow: None.

Power System: Cable to trailer mounted transformer.

Haulage: Muck by diesel shuttle car to conveyor, personnel and supplies by diesel truck.

Support System: 5/8" rock bolts, normally 6' long on 4'x4' spacing, as required.

#### EXCAVATION DATA:

Machine: Atlas-Copco 4 head prototype. Weight: 180 LT. Two 4' dia. heads are mounted on each side of center on horizontal booms rotated about vertical pivots. Heads are rotated around boom centerlines by motors and reducers integral with the booms; booms and heads rotate from side to forward positions.

Cutters: 48 Sandvik T.C., drag type, mounted on head peripheries. Leading cutters, 40mm wide, 8 per head; Finish cutters, 120mm wide, 4 per head.

Rotation: Upper heads: 3 1/4 RPM. Lower: 1 5/8 RPM.

Torque: Head rotation: 80 KW. Boom rotation: 100 LT per boom.

Thrust: 488 LT produced by 4 hydraulic cylinders between advanced and front units.

Anchorage: Two top and two side cylinders, approximately 1,000 K#.

Muck Collection: Flight conveyors move muck from sides to a central 26" flight conveyor, discharging on a 9 1/2' dia. star wheel. The wheel feeds a 25" belt conveyor, transferring muck to a Joy loader and shuttle cars.

Power System: 4160/600/120V, 60 Hz. Head rotation: 4-80 KW motors, hydraulics: 2-78 KW motors, 2300 psi.

Guidance: Transit/Laser.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056" : 0

Spec. Gravity, Material  
Size (-) 0.75" : 2.78

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.80 %

Plastic Limit 15.60 %

Shrinkage Limit 13.26 %

Plasticity Index 0.20 %

Toughness Index 0.05 %

Flow Index 4.00 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 0.9 % Moisture, 28°

@ 0.2 % Moisture, 282

@ 0.9 % Moisture, 29°

Angle Slide Steel Plate

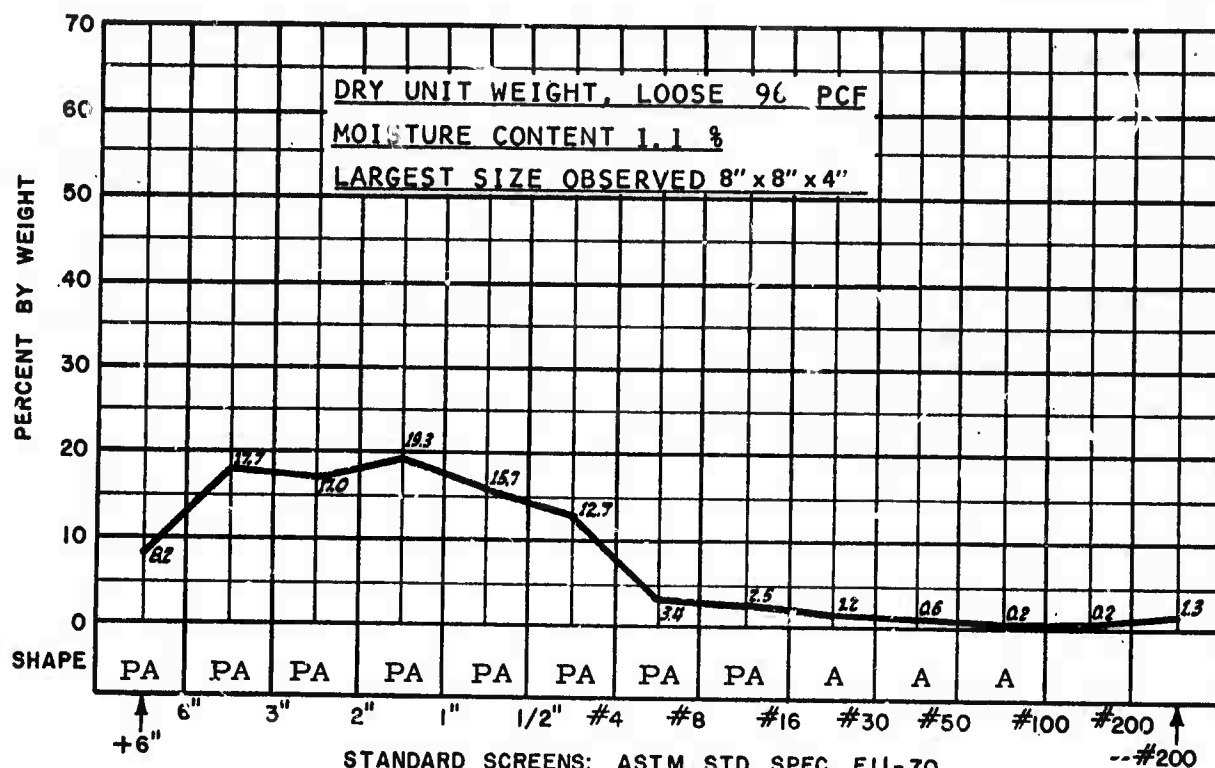
Bulk Density PCF

Angle Internal Friction

@ 0.9 % Moisture, 28°

@ 0.0 % Moisture, 100

@ 0.2 % Moisture, 54°



## MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

### SUMMARY

Rock Class: Sedimentary: Shale and siltstone, minor sandstone and limestone, thin to massive, fine to coarse grained. High strength. RQD (Est.) 90%.  
DUW: 166 PCF. Ground water: Dry. Hardness: Shore 41-55.

System Class: TBM, Atlas-Copco. 18' wide x 8-1/2' rect. heading. Sandvik TC "drag" bits. 12/head, 4 heads. RPM 3 1/4 normal. Torque 80 KW/head, 100LT/boom. 480LT thrust. Mucking: Flight conveyor - starwheel-belt-loader. Haulage: Shuttle car to conveyor. Support: Rock bolts at 4'.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. 11-4  
Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, "shale", massive to thinly laminated, interbedded siltstone and shale, with minor sandstone and limestone layers. Locally highly faulted and fractured. Grain size varies from fine to coarse.  
Uniaxial Compressive Strength: 22K PSI (weighted average).  
RQD: (Estimated) 65%.  
Dry Unit Weight: 168 PCF.  
Ground Water: None.  
Hardness: Shore 41 to 55 parallel to bedding planes, 41 to 54 perpendicular.

#### TUNNEL DATA:

Size: 18'-1" diameter. Grade: (+) 10%.  
Ventilation System: 18K CFM, exhaust, 36" diameter pipe, 120 HP @ 7200'.  
Utility System: 2" water, 4" pump line from sump at 4200' approximate.  
Water Inflow: 5-10 gpm.  
Power System: 4160/480V.  
Haulage System Muck, 30" - "piggy back" conveyor supported by monorail advances with TBM, feeds a 36" conveyor suspended from back of tunnel.  
Supply and Personnel: Diesel jeeps and trucks.  
Support System: 6" x 8.2# channels x 13.5' at 2', secured by 6-5/8" x 6" rock bolts, lagging under channels.

#### EXCAVATION DATA:

Machine: Robbins 181-122. Total weight: 260 tons.  
Cutters: 47 Robbins, steel disc, w/Esco rings, Gage: 3-12".  
Center: 1-7 1/2" triple. Interior 43-12".  
Rotation: 4 1/2 RPM  
Torque: 1,147 K#.   
Thrust: 769K#.   
Muck System: Buckets fixed to head, discharge on conveyors.  
Power System: Four - 480V, 200 HP motors drive head.  
Guidance: Laser

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-)0.056" : 0

Spec. Gravity, Material  
Size (-)0.75" : 2.72

## ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 18.00 %  
Plasticity Index 0.90 %

Plastic Limit 17.10 %  
Toughness Index 0.20 %

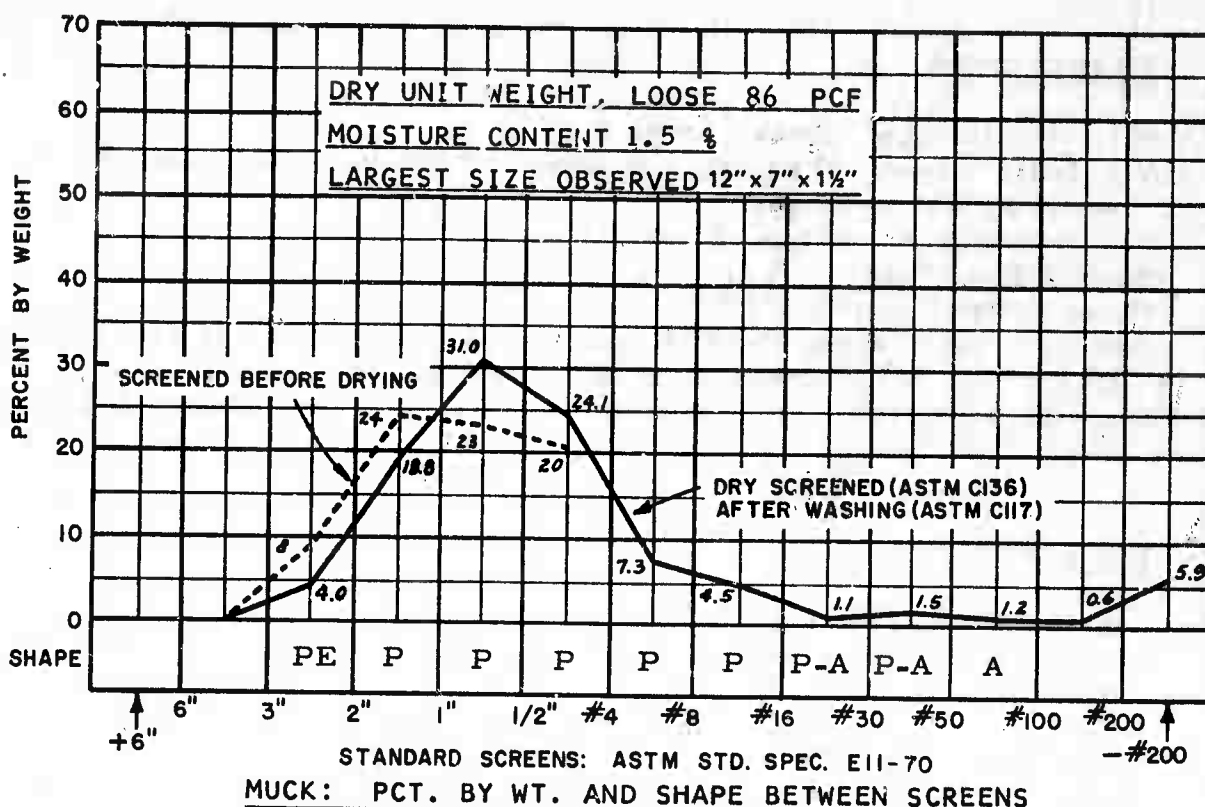
Shrinkage Limit 15.58 %  
Flow Index 4.40 %

## MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop  
@ 1.3 % Moisture, 36°  
Angle Slide Steel Plate  
@ 1.3 % Moisture, 30°

Apparent Cohesion PSF  
@ 1.0 % Moisture, 170  
Bulk Density PCF  
@ 0.0 % Moisture, 100

Angle/Repose 10" Drop  
@ 1.3 % Moisture, 32°  
Angle Internal Friction  
@ 1.0 % Moisture, 41°



## SUMMARY

**Rock Class:** Sedimentary: "Shale" siltstone and shale interbedded, minor sandstone and limestone layers. Massive to thinly laminated, fine to coarse grained. High strength. RQD (Est.) 65%. DUW: 168 PCF. Ground water: None. Hardness: 41 - 55 shore.

**System Class:** TBM, Robbins 181-122, 18'1" dia. 47 Robbins disc cutters. 4-1/2 RPM, 1,476 K FT # Torque, 769 K# Thrust. Mucking: Buckets to belt. Haulage: Conveyor.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. 72-1  
Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, conglomerate ("breccia") 1/4"-10" rounded to angular boulders, cobbles, pebbles in a predominantly limestone matrix, w/chert, schist diabase fragments, well to moderately consolidated.

Uniaxial Compressive Strength: NA.

RQD: (Estimated) 65%.

Dry Unit Weight: 171 PCF

Ground Water: Normally dry.

Hardness: NA.

#### TUNNEL DATA:

Size: 9' x 10' high. Grade: Level.

Ventilation System: 10 KCFM, pressure, 24" diameter pipe, 50 HP @ 1000', from coil heat exchanger.

Utility System: 6" air line, 2" water line.

Water Inflow: None.

Power System: 4160/480/120V.

Haulage System: Muck, supplies, personnel by railcars, 4 and 6 ton battery locomotives 44 CF rocker dump cars, 18" gage, 30# rail.

Support System: 5/8" x 6' rock bolts, 3', 4 1/2' or 6' roof plates, 21 bolts and 7 plates per 5' span.

#### EXCAVATION DATA:

Conventional Rail System.

Drilling: 3 boom hydraulic jumbo, 7' chain feeds, and 3" bore drifters, 7/8" hex steel.

Drill Round: 42 to 50-1 3/8" diameter holes including 4 hole V cut and 4 hole baby V or 5 hole burn cut, average advance 5 1/2'.

Explosives: 150#, 25# Amogel, #4-40% primers and cushion, 125# Carbamite PB. Powder Factor, 8.2#/CY.

Blasting: #6 caps, 8' fuse, detonated electrically, timed by order of connection to igniter cord.

Mucking System: Eimco Model 21 Loader.

Guidance: Laser

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. MSU-1  
Sheet 1

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size(-) 0.056" : 0

Spec. Gravity, Material  
Size(-) 0.75" : 2.74

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 13.80 %  
Plasticity Index 1.03 %

Plastic Limit 12.77 %  
Toughness Index 0.32 %

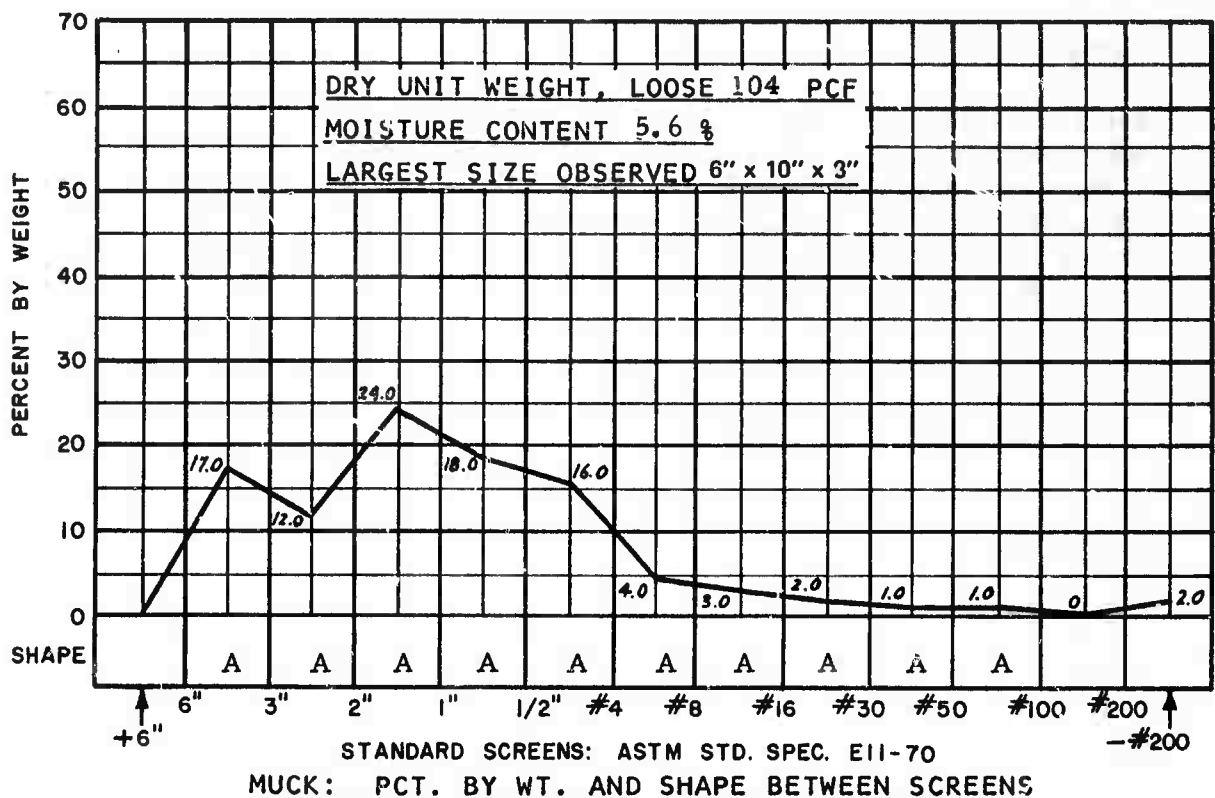
Shrinkage Limit 10.78%  
Flow Index 3.20 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 0.4 % Moisture, 35°  
Angle Slide Steel Plate  
@ 0.4 % Moisture, 27°

Apparent Cohesion PSF  
@ 0.3 % Moisture, 410  
Bulk Density PCF  
@ 0.0 % Moisture, 111

Angle/Repose 10" Drop  
@ 0.4 % Moisture, 29°  
Angle Internal Friction  
@ 0.3 % Moisture, 46°



## SUMMARY

Rock Class: Sedimentary: Conglomerate, "breccia," 1/4" to 10", limestone, chert, schist, diabase fragments, well to moderately consolidated. Strength, NA. RQD (Est.) 65%. DUW: 171 PCF. Ground water: Dry. Hardness, NA.

System Class: Conventional Rail, 9' wide x 10', three boom jumbo, 42 to 50-1-3/8" holes, burn cut. PF 8.2 #/CY. Mucking: Eimco 21. Haulage: Rail. Support: Rock bolts and plates, continuous.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. MSU-1  
Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, conglomerate, ("breccia") 1/4"-4" boulders, cobbles, and pebbles, rounded to angular in a predominantly limestone matrix, w/chert, schist and diabase fragments, well consolidated.

Uniaxial Compressive Strength: NA.

RQD: (Estimated) 80%.

Dry Unit Weight: 171 PCF

Ground Water: None

Hardness: NA.

#### TUNNEL DATA:

Size: 9' wide x 10' high, arched. Grade: Level.

Ventilation System: 9 KCFM, pressure, 24" diameter pipe, 50 HP @ 1300' from coil heat exchanger.

Utility System: 6" air line, 2" water line.

Water Inflow: None.

Power System: 4160/480/120V.

Haulage System: Muck, supplies, personnel by railcars, 4 and 6 ton battery locomotives, 44 cu. ft. rocker dump cars, 18" gage, 30# rail.

Support System: 5/8" x 6' rock bolts, 3', 4 1/2' or 6' roof plates, 21 bolts and 7 plates per 5' span.

#### EXCAVATION DATA:

Conventional Rail System.

Drilling: 2 boom jumbo, 6' chain feeds and 3" bore drifters.

Drill Round: 50-1 3/8" diameter holes, including 4 hole V cut and 4 hole baby V, 5 1/2' average advance.

Explosives: 122# average, 40% Amogel #4 or 40% primers and carbamite. Powder Factor, 6.7#/CY.

Blasting: #6 caps, 8' fuse, detonated electrically, timed by order of connection to igniter cord.

Mucking System: Eimco Model 21 loader.

Guidance: Laser.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. MSU-2  
Sheet 1



# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size : NA

Spec. Gravity, Material  
Size : NA

## ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %  
Plasticity Index NA %

Plastic Limit NA %  
Toughness Index NA %

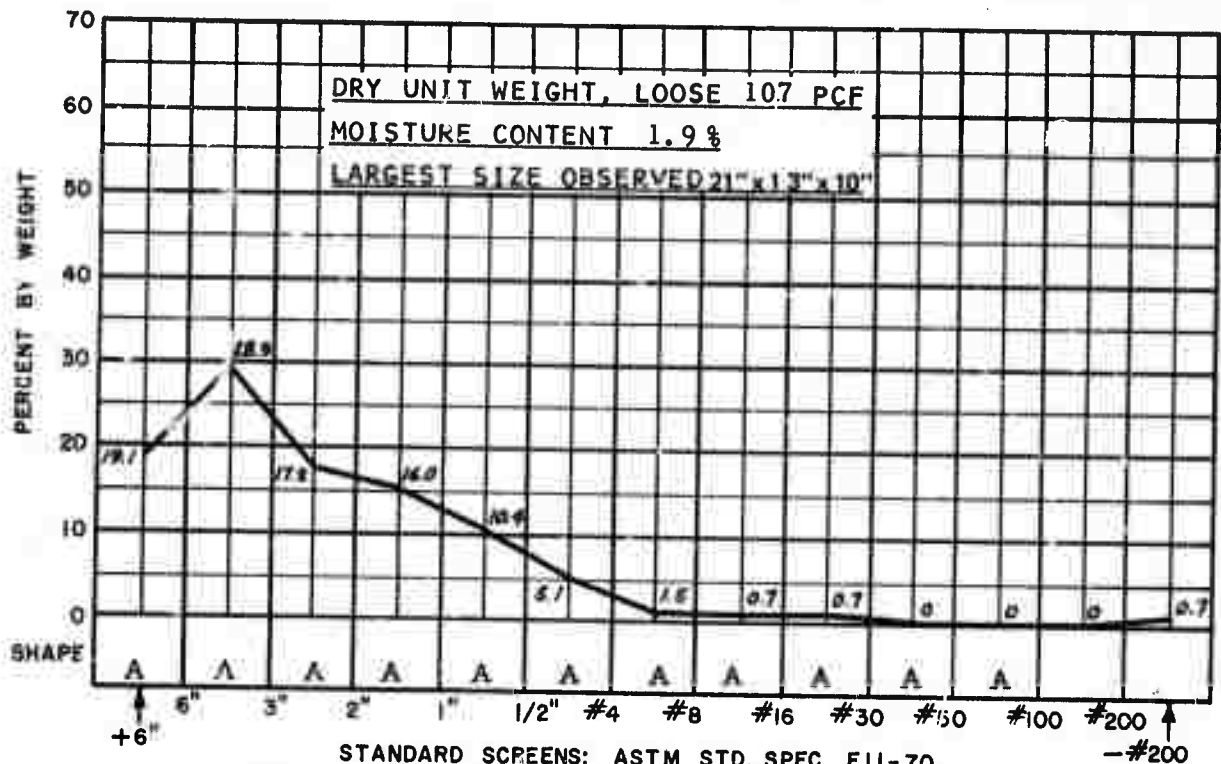
Shrinkage Limit NA %  
Flow Index NA %

## MATERIAL SIZE IN.

Angle/Repose 1" Drop  
@ % Moisture, NA  
Angle Slide Steel Plate  
@ % Moisture, NA

Apparent Cohesion PSF  
@ % Moisture, NA  
Bulk Density PCF  
@ % Moisture, NA

Angle/Repose 10" Drop  
@ % Moisture, NA  
Angle Internal Friction  
@ % Moisture, NA



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Conglomerate, "breccia," 1/4" - 4" limestone, chert schist, diabase fragments, well consolidated. Strength: NA. RQD (Est.) 80%.  
DUW: 171 PCF. Ground water: None. Hardness: NA.

System Class: Conventional Rail. 9' wide x 10'. Two machine jumbo, 50 holes, V cut. PF 6.7 #/CY. Mucking: Eimco 21. Haulage: Rail. Support: Roof plates and rock bolts, continuous.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. MSU-2  
Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, limestone, light to medium gray, fine grained, some chert nodules, traces to occasional clay partings.

Uniaxial Compressive Strength: 19 KPSI

RQD: (Estimated) 100 percent.

Dry Unit Weight: 160 PCF.

Ground Water: Table above tunnel, occasional seepage from minor fractures and faults.

Hardness: Shore, 46.

#### TUNNEL DATA:

Size: 13'-8" diameter. Grade (+) 1/4 percent.

Ventilation System: 21 K CFM exhaust, 28" pipe.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 40 to 120 gpm.

Power System: 4160/480V.

Haulage System: Muck, supplies, personnel, by rail cars.

Support System: None.

#### EXCAVATION DATA:

Machine: Alkirk Hardrock. Weight 400 tons. Cutters: 28-Lawrence Mfg. Company, Tungsten Carbide Button, roller, disc, and tricone. Gage: 5-15" TCB roller. Center: 1-24" TCB tricone. Interior: 11-15" TCB disc., 11-15" TCB roller.

Rotation: Center cutter-30 RPM, Head-9 RPM.

Torque: Head 206 K ft. #

Thrust: 614 K# operating

Muck Collection: Buckets from face discharging on 24" belt conveyor.

Power System: Electro-Hydraulic. Total HP: 910.

Guidance System: Laser.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.065": 0

Spec. Gravity, Material  
Size (-) 0.75": 2.83

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.185 IN.

Liquid Limit 12.5 %

Plastic Limit 12.3 %

Shrinkage Limit 9.6 %

Plasticity Index 0.2 %

Toughness Index 0.05 %

Flow Index 4.0 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 5.4 % Moisture, 39°

@ % Moisture, NA

@ 5.4 % Moisture, 38°

Angle Slide Steel Plate

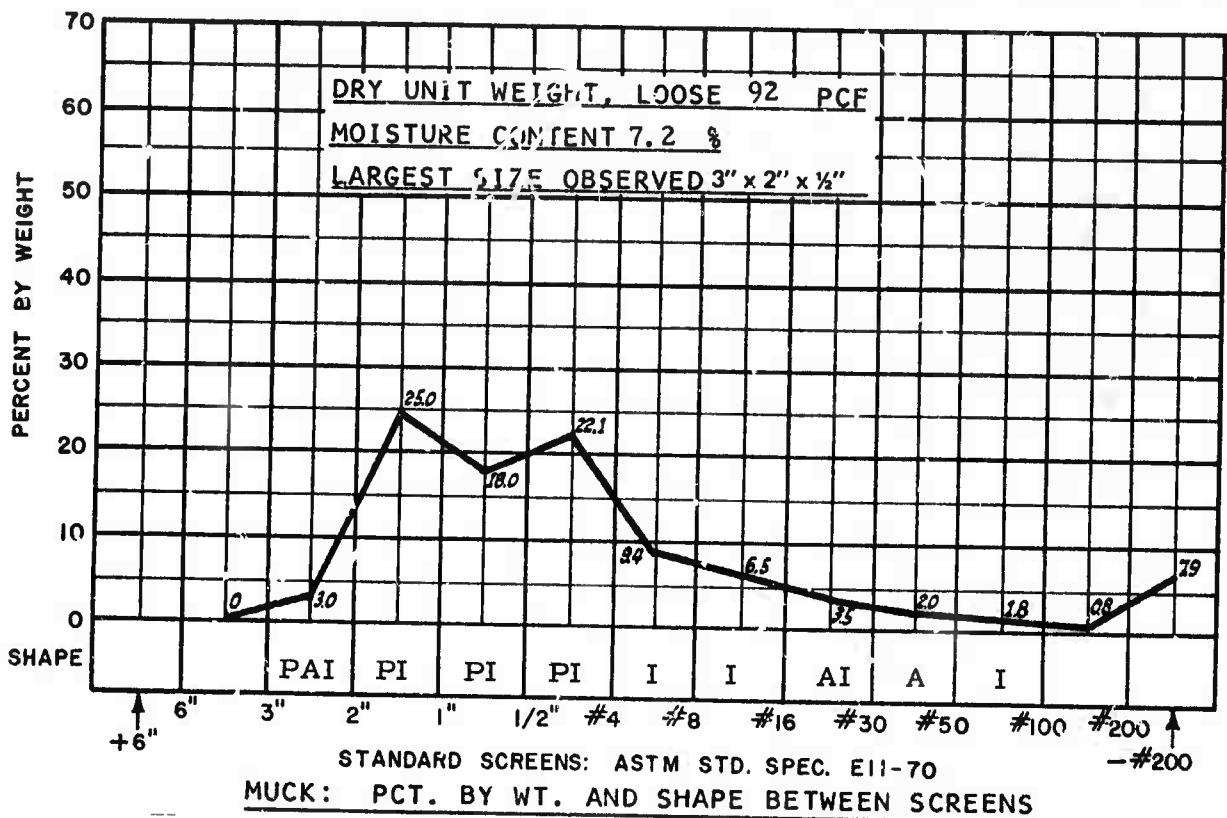
Bulk Density PCF

Angle Internal Friction

@ 5.4 % Moisture, 31°

@ % Moisture, NA

@ 7 % Moisture, 30°



## SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, some chert nodules, occasional clay partings. High strength. RQD (Est.) 100%. DUW: 160 PCF. Ground water: Minor. Hardness: Shore 46.

System Class: TBM, Alkirk Hardrock, 13' 8" dia. 28 Lawrence TCB roller, disc, tricone cutters. RPM: Center 30, head 9. Torque: 206 K ft #. Thrust: 614 K #. Mucking: Buckets to belt. Haulage: Rail. Support: None.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LAW-2  
Sheet 2

### ROCK DATA:

Lithology: Sedimentary, limestone, light to medium gray, fine grained, some chert nodules, traces to occasional clay partings.  
Uniaxial Compressive Strength: 19 KPSI.  
RQD: (Estimated) 100 percent.  
Dry Unit Weight: 160 PCF.  
Ground Water: Table above tunnel, occasional seepage from minor fractures and faults.  
Hardness: Shore, 46.

### TUNNEL DATA:

Size: 13'-8" diameter. Grade (+) 1/4 percent.  
Ventilation System: 20 K CFM exhaust, 28" pipe.  
Utility System: 6" air line, 2" water line, 6" pump line.  
Water Inflow: 40 to 120 gpm.  
Power System: 4160/480V.  
Haulage System: Muck, supplies, personnel, by rail cars.  
Support System: None.

### EXCAVATION DATA:

Machine: Alkirk Hardrock. Weight 400 tons. Cutters: 28-Lawrence Mfg. Company, Tungsten Carbide Button, roller, disc, and tricone. Gage: 5-15" TCB roller. Center: 1-24" TCB tricone. Interior: 11-15" TCB disc., 11-15" TCB roller.  
Rotation: Center cutter-30 RPM, Head-9 RPM.  
Torque: 206 K ft. #.  
Thrust: 614 K# operating.  
Muck Collection: Buckets from face, discharging on 24" belt conveyor.  
Power System: Electro-Hydraulic. Total HP: 910.  
Guidance System: Laser.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LAW-3  
Sheet 1

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.065" : 0

Spec. Gravity, Material  
Size (-) 0.75" : 2.80

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.185 IN.

Liquid Limit 11.8 %

Plastic Limit 10.6 %

Shrinkage Limit 10.0 %

Plasticity Index 1.2 %

Toughness Index 0.41 %

Flow Index 2.9 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 6.1% Moisture, 41°

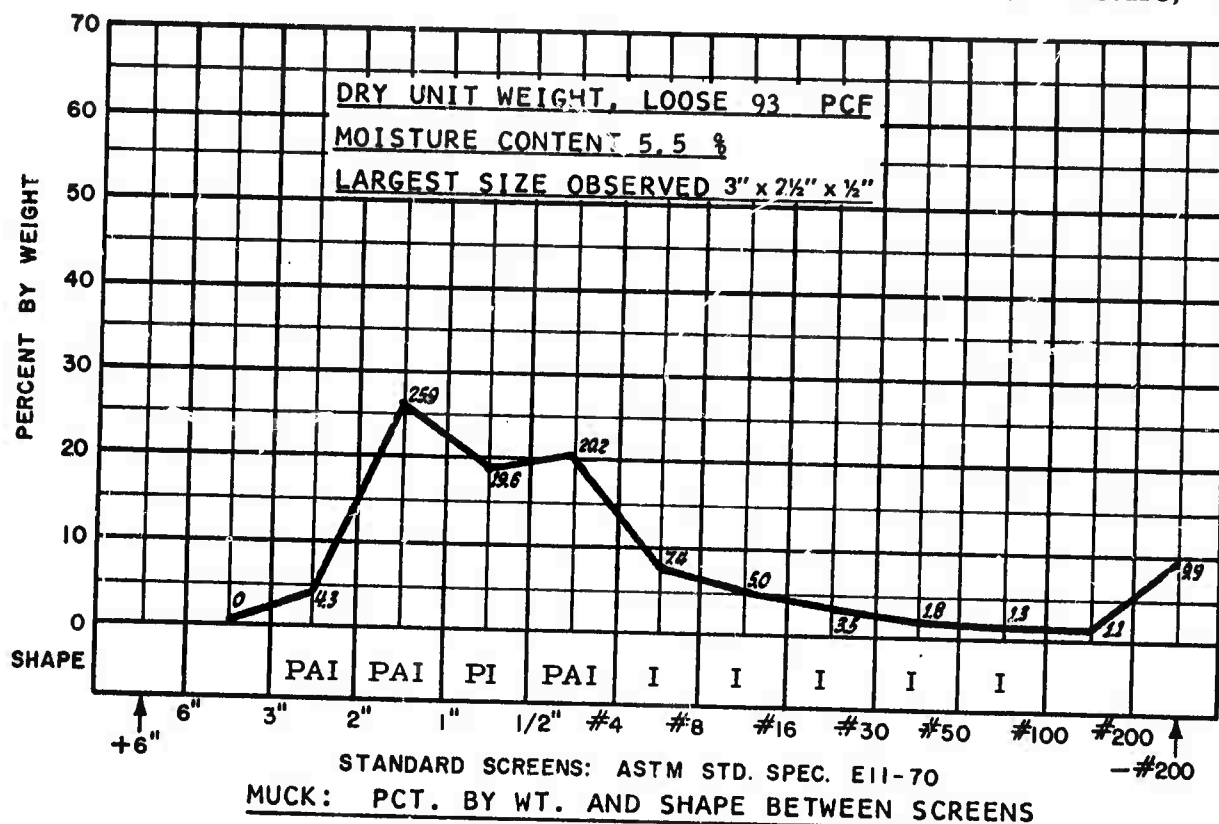
Apparent Cohesion PSF  
@ % Moisture, NA

Angle/Repose 10" Drop  
@ 6.1 % Moisture, 40°

Angle Slide Steel Plate  
@ 8.4 % Moisture, 38°

Bulk Density PCF  
@ % Moisture, NA

Angle Internal Friction  
@ 7 % Moisture, 32°



## SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, some chert nodules occasional clay partings. High strength. RQD (Est.) 100%. DUW: 160 PCF. Ground water: Minor. Hardness: Shore 46.

System Class: TBM, Alkirk Hardrock, 13' 8" dia. 28 Lawrence TCB roller, disc, tricone cutters. RPM: Center 30, head 9. Torque: 206 K ft #. Thrust: 614 K #. Mucking: Buckets to belt. Haulage: Rail. Support: None.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LAW-3  
Sh. et 2

#### ROCK DATA:

Lithology: Sedimentary, limestone, light to medium gray, fine grained, some chert nodules, traces to occasional clay partings.

Uniaxial Compressive Strength: 19 KPSI.

RQD: (Estimated) 100 percent.

Dry Unit Weight: 160 PCF.

Ground Water: Table above tunnel, occasional seepage from minor fractures and faults.

Hardness: Shore, 46.

#### TUNNEL DATA:

Size: 13'-8" diameter. Grade (+) 1/4 percent.

Ventilation System: 21 K CFM exhaust, 28" pipe.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 40 to 120 gpm.

Power System: 4160/480V.

Haulage System: Muck, supplies, personnel, by rail cars.

Support System: None.

#### EXCAVATION DATA:

Machine: Alkirk Hardrock. Weight 400 tons. Cutters: 28-Lawrence Mfg. Company, Tungsten Carbide Button, roller, disc, and tricone.

Gage: 5-15" TCB roller. Center: 1-24" TCB tricone. Interior: 11-15" TCB disc., 11-15" TCB roller.

Rotation: Center cutter-30 RPM, Head-9 RPM.

Torque: Head 206 K ft. #.

Thrust: 540 K ft. #.

Muck Collection: Buckets from face discharging on 24" belt conveyor.

Power System: Electro-Hydraulic. Total HP: 910.

Guidance System: Laser.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056" : 0

Spec. Gravity, Material  
Size (-) 0.75" : 2.73

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 20.2 %

Plastic Limit 20.0 %

Shrinkage Limit 13.5 %

Plasticity Index 0.2 %

Toughness Index 0.95 %

Flow Index 4.7 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 8.9 % Moisture, 42°

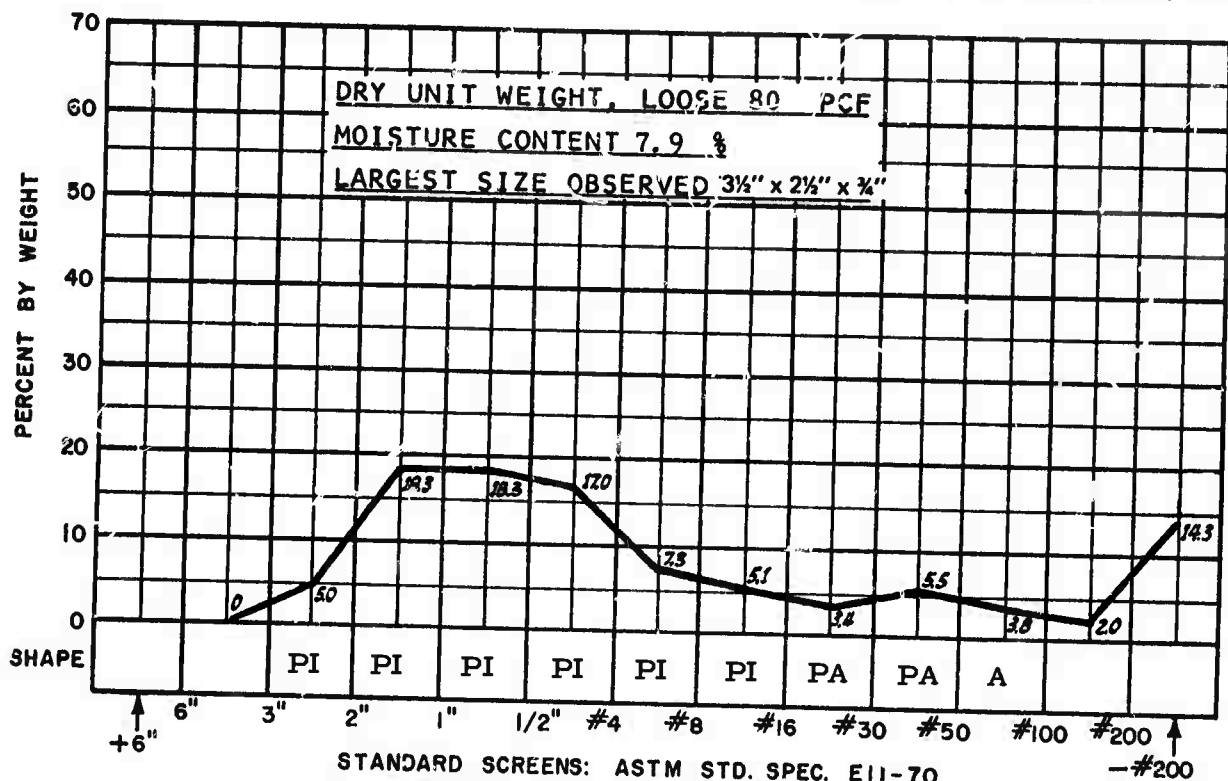
Apparent Cohesion PSF  
@ % Moisture, NA

Angle/Repose 10" Drop  
@ 8.9 % Moisture, 34°

Angle Slide Steel Plate  
@ 8.9 % Moisture, 37°

Bulk Density PCF  
@ % Moisture, NA

Angle Internal Friction  
@ 8.8 % Moisture, 28°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, some chert nodules, occasional clay partings. High strength. RQD (Est.) 100%. DUW: 160 PCF. Ground water: Minor. Hardness: Shore 46.

System Class: TBM, Alkirk hardrock, 13' 8" dia. 28 Lawrence TCB roller, disc, tricone cutters. RPM: Center 30, head 9. Torque: 206 K ft #. Thrust: 540 K #. Mucking: Buckets to belt. Haulage: Rail. Support: None.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LAW-4  
Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestone, gray, fine grained, horizontal joint spacing 6" to 1'.

Uniaxial Compressive Strength: 36 KPSI.

RQD: (Estimated) 85%

Dry Unit Weight: 166 PCF.

Ground Water: Minor, in fault zones.

Hardness: NA

TUNNEL DATA:

Size: 11'-2" round. Grade: (+) .2%.

Ventilation System: 4 KCFM, exhaust, 18" pipe, 25 HP.

Utility System: 6" air line, 1" water line, 6" pump line.

Water Inflow: 5-10 gpm.

Power System: 4680/440V.

Haulage System: Muck, supplies, personnel, rail cars, 5 ton motors, track gage 24".

Support System: 4" H rings sets in fault zones, occasional pinned steel lagging.

EXCAVATION DATA:

Machine: Jarva Mark 11-1100. Total weight: 65 tons.

Cutters: 27 Reed steel triple disc and cone. Gage: 4-QK5 steel disc.

Center: 1-QK1 steel cone. Interior: 22-QK3 steel disc.

Rotation: Cutterhead RPM 9.3.

Torque: Maximum 170 K ft#.

Thrust: 1,104 K# maximum, 596 K #-operating. Anchor Pressure: 1,650 K#.

Muck Collection: Bucket from face to 18" belt to 24" belt on gantry.

Power System: 440 volt, 6 - 50 HP motors drive head and 1-40 HP motor for hydraulic system.

Guidance: Laser.



# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056" : 0

Spec. Gravity, Material  
Size (-) 0.75" : 2.89

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 16.90%

Plastic Limit 15.69%

Shrinkage Limit 15.46 %

Plasticity Index 1.21 %

Toughness Index 0.24 %

Flow Index 5.00 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 2.5 % Moisture, 36°

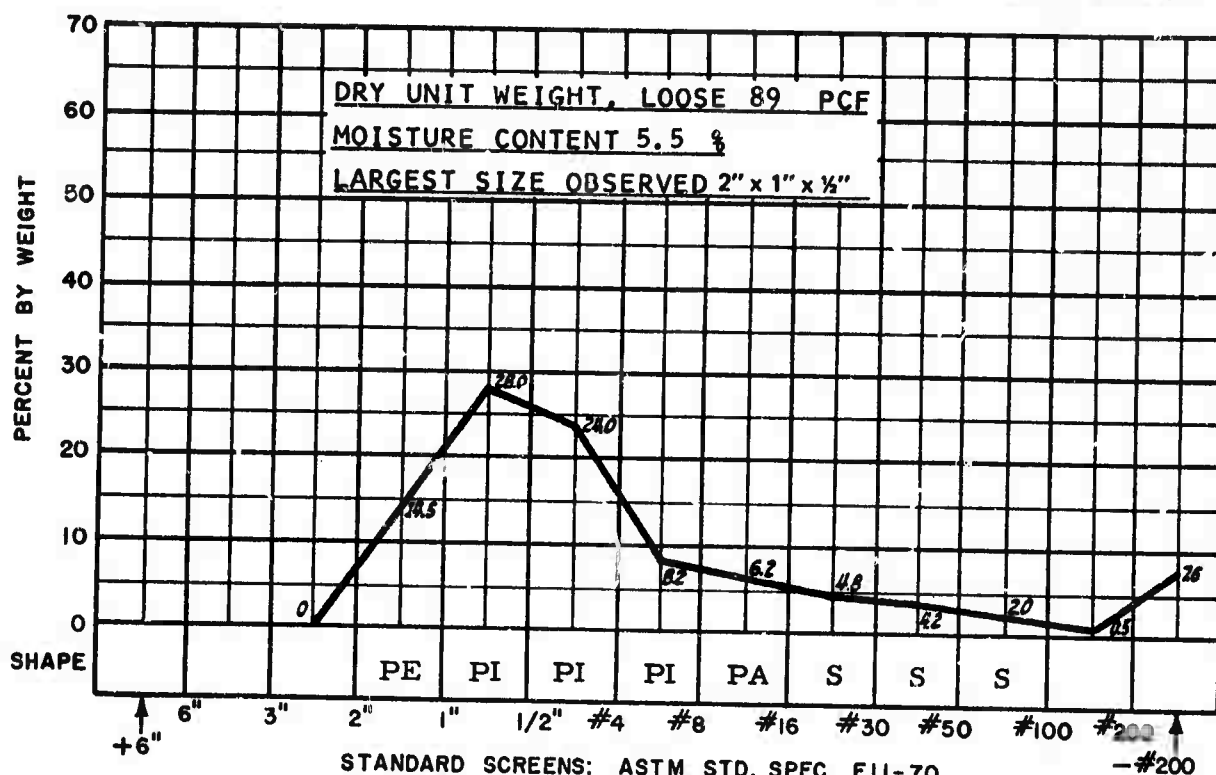
Apparent Cohesion PSF  
@ 4.1 % Moisture, 95

Angle/Repose 10" Drop  
@ 2.5 % Moisture, 35°

Angle Slide Steel Plate  
@ 2.5 % Moisture, 30°

Bulk Density PCF  
@ 0.0 % Moisture, 86

Angle Internal Friction  
@ 3.5 % Moisture, 35°



## SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, horizontal joint spacing 6" to 1'. Strength: Very high. RQD (Est.) 85%. DUW: 166 PCF.  
Ground water: Minor. Hardness: NA.

System Class: TBM, Jarva Mark 11-100, 11' 2" dia. 27 Reed triple disc cutters/cone. RPM: 9.3. Torque: 170 K ft #. Thrust: 596 K #. Mucking: Bucket to belt. Haulage: Rail. Support: H ring sets in fault zones.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. MIL-1  
Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestone, gray, fine grained, horizontal joint spacing 6" to 1'.

Uniaxial Compressive Strength: 36 KPSI.

RQD: (Estimated) 85%

Dry Unit Weight: 166 PCF.

Ground Water: Minor, in fault zones.

Hardness: NA

TUNNEL DATA:

Size: 11'2" round, Grade: (+) .2%.

Ventilation System: 4KCFM, exhaust, 18" pipe, 25 HP.

Utility System: 6" air line, 1" water line, 6" pump line.

Water Inflow: 5-10 gpm.

Power System: 4680/440V.

Haulage System: Muck, supplies, personnel, rail cars, 5 ton motors, track gage 24".

Support System: 4" H rings sets in fault zones, occasional pinned steel lagging.

EXCAVATION DATA:

Machine: Jarva 11-1100, Total weight: 65 tons.

Cutters: 27 Reed steel triple disc and cone. Gage: 4-QK5 steel disc.

Center: 1-QK1 steel cone. Interior: 22-QK3 steel disc.

Rotation: Cutterhead RPM 9.3.

Torque: Maximum 170 K ft. #.

Thrust: 1,104 K# maximum, 596 K#-operating Anchor Pressure: 1,650 K#.

Muck Collection: Bucket from face to 18" belt to 24" belt on gant. y.

Power System: 440 volt, 6-50 HP motors drive head and 1-40 HP motor for hydraulic system.

Guidance: Laser.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056": 0

Spec. Gravity, Material  
Size (-) 0.75": 2.93

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 20.10%

Plastic Limit 16.68 %

Shrinkage Limit 16.37 %

Plasticity Index 3.42 %

Toughness Index 0.56 %

Flow Index 6.10 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 5.8 % Moisture, 32°

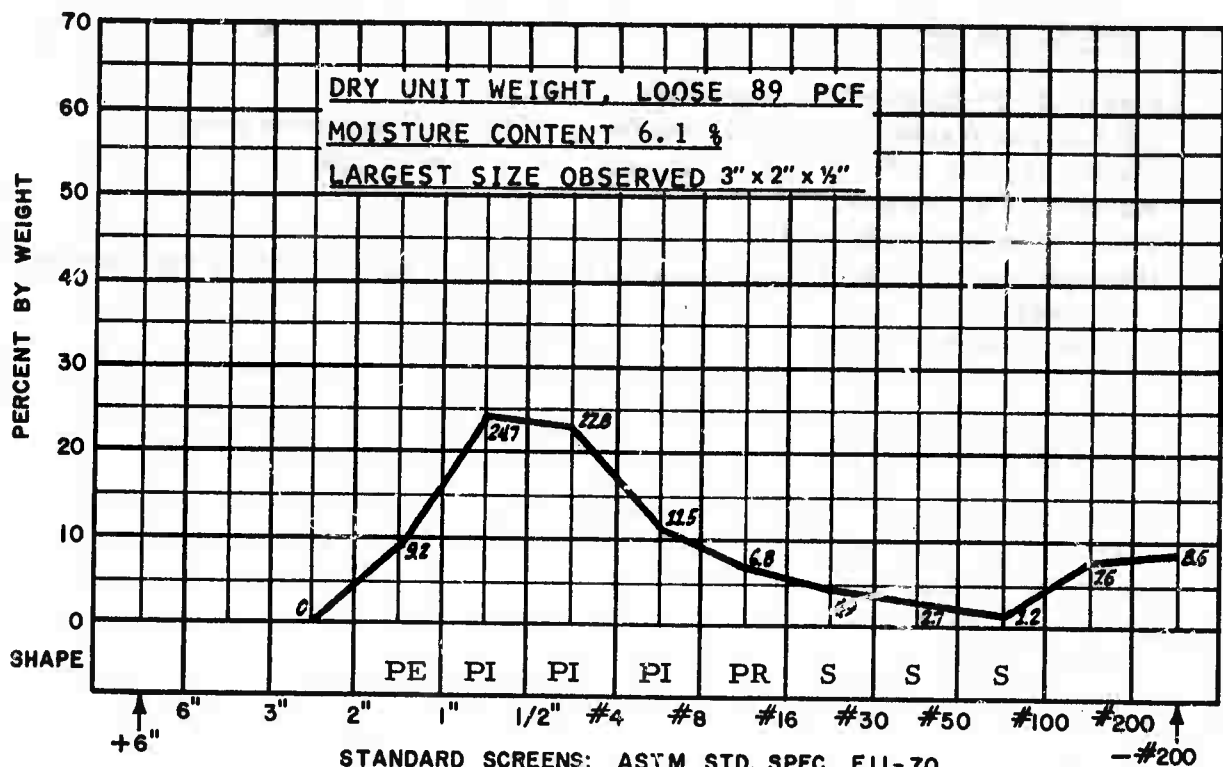
Apparent Cohesion PSF  
@ 5.0 % Moisture, 110

Angle/Repose 10" Drop  
@ 5.8 % Moisture, 30°

Angle Slide Steel Plate  
@ 5.8 % Moisture, 30°

Bulk Density PCF  
@ 0.0 % Moisture, 90

Angle Internal Friction  
@ 5.0 % Moisture, 33°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, horizontal joint spacing 6" to 1'. Strength: Very high. RQD (Est.) 85%. DUW: 166 PCF. Ground water: Minor. Hardness: NA.

System Class: TBM, Jarva Mark 11-100, 11'2" dia. 27 Reed triple disc cutters. RPM: 9.3. Torque: 170 K ft #. Thrust: 596 K #. Mucking: Bucket to belt. Haulage: Rail. Support: H ring sets in fault zones.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. MIL-2  
Sheet 2

**ROCK DATA:**

Lithology: Sedimentary, limestone, grey, fine grained, horizontal joint spacing 4"-8".

Uniaxial Compressive Strength: 24K PSI.

RQD: (Estimated) 81%.

Dry Unit Weight: 164 PCF

Ground Water: Dry.

Hardness: NA.

**TUNNEL DATA:**

Size: 11' 2" diameter. Grade: (+) 0.2%.

Ventilation System: 4 KCFM, exhaust, 25 HP (through bore hole).

Utility System: 6" air line, 1" water line, 6" pump line.

Water Inflow: Minor.

Power System: 4680/440V.

Haulage System: Muck, supplies, personnel by railcars, 5 ton locomotive, 24" gage.

Support System: None.

**EXCAVATION DATA:**

Machine: Jarva, 11-1100, total weight 65 tons.

Cutters: 27 Reed steel disc: 4 gage QK5, 22 interior 2K3, 1 center QK1.

Rotation: 9.3 RPM.

Torque: 119K ft. lbs.

Thrust: 639K#

Muck Collection System: Buckets from face, belt to rear.

Power System: 6-50 HP motors drivehead, 1-40 HP motor for hydraulic system.

Guidance: Laser.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size(-)0.056" : 0

Spec. Gravity, Material  
Size (-)0.75" : 2.78

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.20 %  
Plasticity Index 0.80 %

Plastic Limit 14.40 %  
Toughness Index 0.22 %

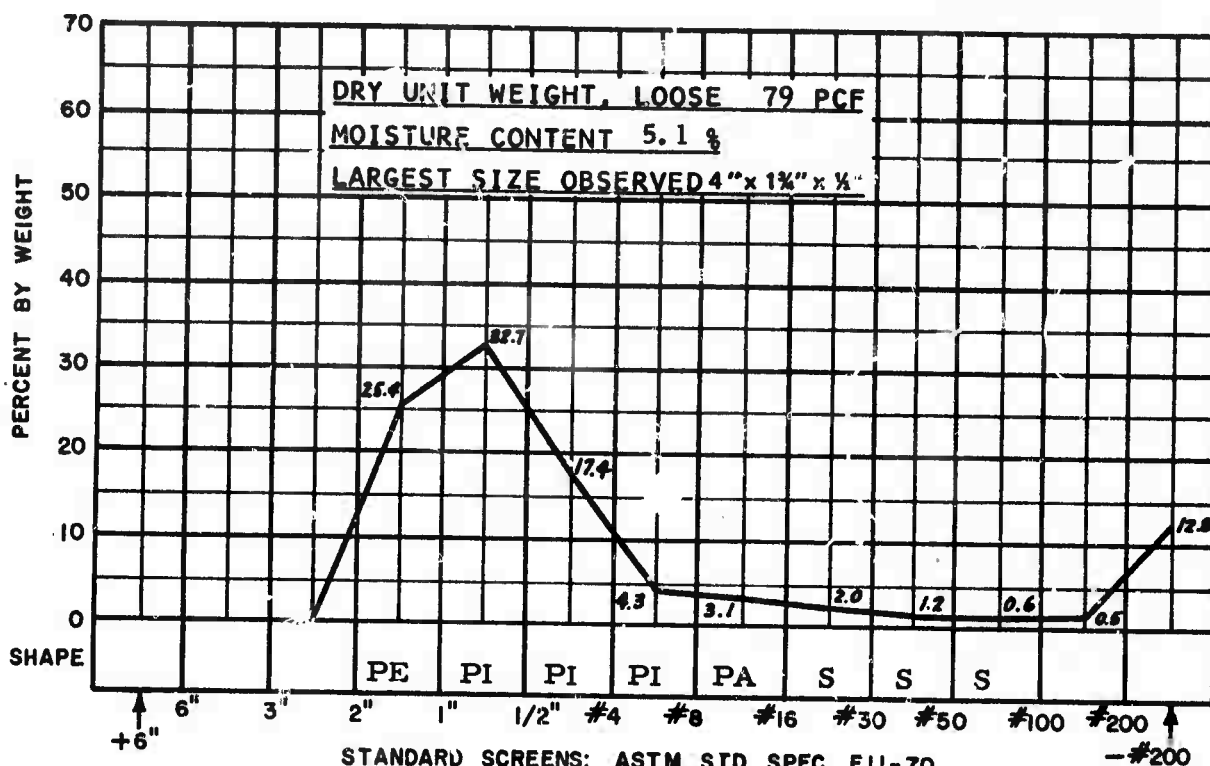
Shrinkage Limit 12.96 %  
Flow Index 3.50 %

## MATERIAL SIZE(-) 2.0 IN.

Angle/Repose 1" Drop  
@ 2.5 % Moisture, 36°  
Angle Slide Steel Plate  
@ 2.5 % Moisture, 32°

Apparent Cohesion PSF  
@ 2.3 % Moisture, 60  
Bulk Density PCF  
@ 0.0 % Moisture, 95

Angle/Repose 10" Drop  
@ 2.5 % Moisture, 32°  
Angle Internal Friction  
@ 2.3 % Moisture, 36°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, horizontal jointing 4"-8".  
High strength. RQD: 81%. DUW: 164 PCF. Ground water: Dry.  
Hardness: NA.

System Class: TBM, Jarva 11-1100, 11'2" dia. 27 Reed disc cutters.  
9.3 RPM, 119 K ft Torque, 639 K # Thrust. Mucking: Buckets to belt.  
Haulage: Rail. Support: None.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. MIL-3  
Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, limestone, light grey, fine grained.

Uniaxial Compressive Strength: 26K PSI.

RQD: 100%.

Dry Unit Weight: 168 PCF

Ground Water: Dry.

Hardness: NA.

#### TUNNEL DATA:

Size: 10' 4" diameter. Grade: (+) 0.2%.

Ventilation: 18 KCFM, exhaust, 30" diameter pipe, 90 HP @ 1980'.

Utility System: 3" water line.

Water Inflow: 300/400 gpm.

Power System: 7200/480V.

Haulage System: Muck, supplies, personnel by railcars, 5 ton locomotive,  
4 CY cars, 24" gage, 54# rail.

Support System: None.

#### EXCAVATION DATA:

Machine: Robbins 105-144. Total weight: 75 tons.

Cutters: 26 Robbins, 12" and 11" discs. 2 Gage and 21 interior, 12" diameter,  
3 center, 11" diameter.

Rotation: 6 RPM.

Torque: 280K ft. lb.

Thrust: 230K lb.

Muck Collection System: Buckets from face, belt to rear.

Power System: 4-100 HP motors drivehead, 50 HP for hydraulic system.

Guidance: Laser.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056" : 0

Spec. Gravity, Material  
Size (-) 0.75": 2.81

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.10%

Plastic Limit 13.69%

Shrinkage Limit 11.57%

Plasticity Index 1.41%

Toughness Index 0.47%

Flow Index 3.0 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 3.1 % Moisture, 37°

@ 3.0 % Moisture, 70

@ 3.1 % Moisture, 31°

Angle Slide Steel Plate

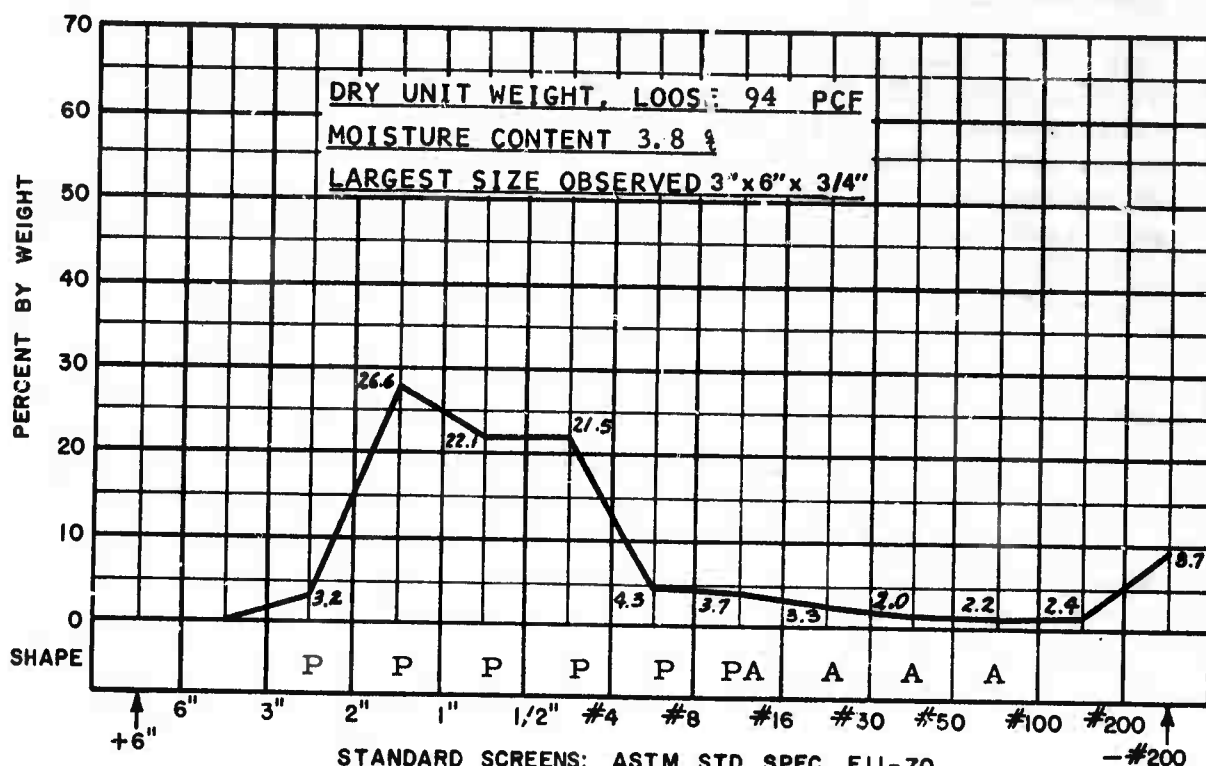
Bulk Density PCF

Angle Internal Friction

@ 3.1 % Moisture, 31°

@ 0.0 % Moisture, 104

@ 3.0 % Moisture, 42°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Limestone fine grained. High strength.  
RQD 100%. DUW: 168 PCF. Ground water: Dry. Hardness, NA.

System Class: TBM, Robbins, 105-144, 10' 4" dia. 26 Robbins disc cutters.  
RPM: 6. 280 K ft # torque, 230 K # thrust. Mucking: Buckets to belt.  
Haulage: Rail. Support: None.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. EVG-1  
Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestone, light grey, fine grained.  
Uniaxial Compressive Strength: NA.  
RQD: 100  
Dry Unit Weight: NA.  
Ground Water: Dry.  
Hardness: NA.

TUNNEL DATA:

Size: 10' 4" diameter. Grade: (+) 0.2%.  
Ventilation System: 18 KCFM, exhaust, 30" diameter pipe, 90 HP.  
Utility System: 3" water line.  
Water Inflow: 300/400 gpm.  
Power System: 7200/480V.  
Haulage System: Muck, supplies, personnel by railcars, 5 ton locomotive,  
4 CY cars, 24" gage, 54# rail.  
Support System: None.

EXCAVATION DATA:

Machine: Robbins 105-144. Total weight: 75 tons.  
Cutters: 26 Robbins 12" and 11" discs, 2 gage and 21 interior-12" diameter  
3 center-11" diameter.  
Rotation: 6 RPM.  
Torque: 246K ft. lb.  
Thrust: 267K lb.  
Muck Collection System: Buckets from face, belt to rear.  
Power System: 4-100 HP motors drivehead, 50 HP for hydraulic system.  
Guidance: Laser.



# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size : NA

Spec. Gravity, Material  
Size : NA

## ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %

Plastic Limit NA %

Shrinkage Limit NA %

Plasticity Index NA %

Toughness Index NA %

Flow Index NA %

## MATERIAL SIZE

IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ % Moisture, NA

@ % Moisture, NA

@ % Moisture, NA

Angle Slide Steel Plate

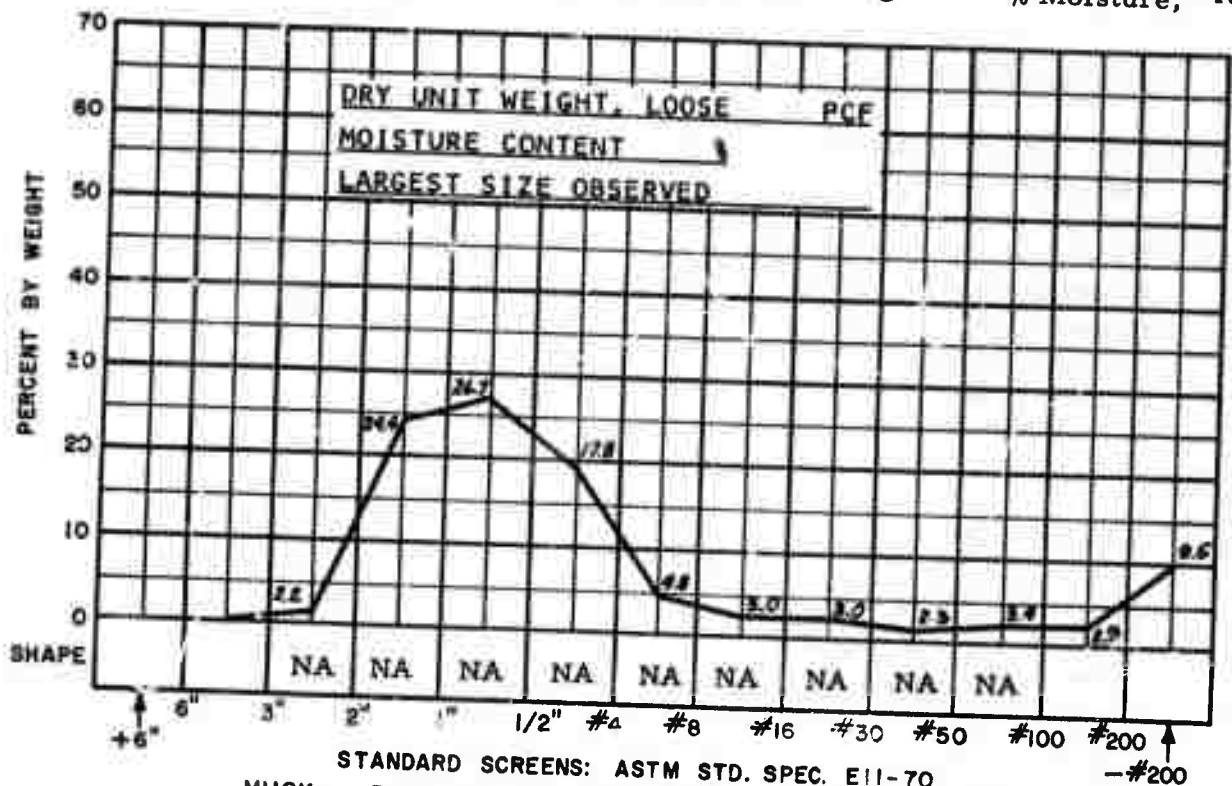
Bulk Density PCF

Angle Internal Friction

@ % Moisture, NA

@ % Moisture, NA

@ % Moisture, NA



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Limestone, fine grained. Strength: NA.  
RQD: 100%. DUW: NA. Ground water: Dry. Hardness: NA.

System Class: TBM Robbins 105-144. 10'-4" dia. 26 Robbins disc cutters.  
RPM: 6. Torque: 246 K ft #. Thrust: 267 K #. Mucking: Buckets to belt.  
Haulage: Rail. Support: None.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. EVG-2  
Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, sandstone, medium grained, light brown to red, massive, porous, poorly cemented.

Uniaxial Compressive Strength: 10 KPSI

RQD: (Estimated) 84%

Dry Unit Weight: 150 PCF

Ground Water: Generally dry.

Hardness: NA

#### TUNNEL DATA:

Size: 12'-11" diameter. Grade: (+) .125%

Ventilation System: 15-17 KCFM exhaust, 36" dia. pipe, 100 HP @ 4100'.

Utility System: 3 1/2" water line, 6" air line, 8" pump line.

Water Inflow: 20-100 gpm.

Power System: 7300/480V

Haulage System: Muck, supplies, personnel, 10 ton locomotives, 10 CY cars, 24" gage, 65 lb. rail.

Support System: 4" H full rings, 4' centers: 35%; 13" x 9' pans 3/4" x 7" rock bolts: 10%.

#### EXCAVATION DATA:

Machine: Robbins 141-127, total weight: 125 tons.

Cutters: 32 Robbins steel disc. Gage: 6-12". Center: 1-11" triple disc. Interior: 23-11".

Rotation: Center cutter integral with head, 5.2 or 2.6 RPM.

Torque: 472 to 524 K ft. #.

Thrust: 331 K# to 382 K#. operating. Anchor pressure: 1,000 K#.

Muck Collection: Pickup by buckets fixed to head, discharging on 30" belt to a 24" x 204' belt on gantry.

Power System: 6-480/240V electric motors drive head. Hydraulic pumps power thrust and gripper cylinders.

Guidance System: Laser

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056": 0

Spec. Gravity, Material  
Size (-) 0.75": 2.66

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 21.20 %  
Plasticity Index 3.14 %

Plastic Limit 17.06 %  
Toughness Index 0.52 %

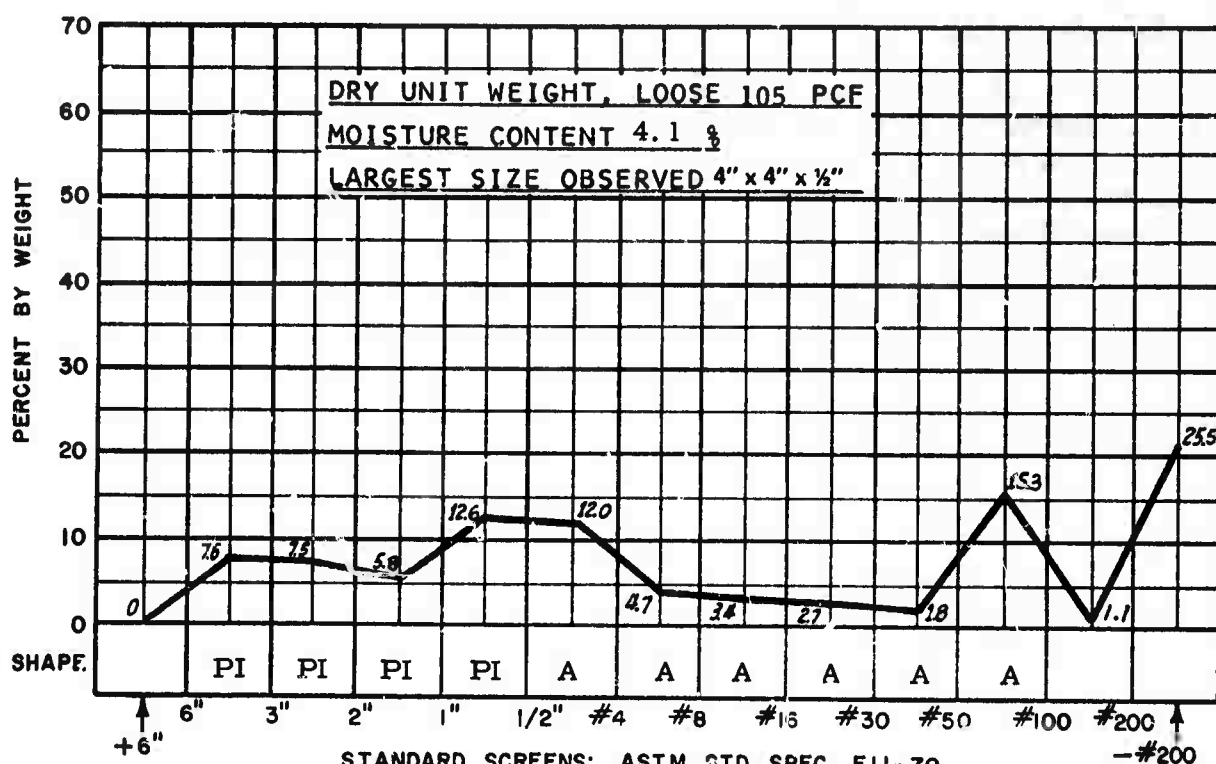
Shrinkage Limit 15.17 %  
Flow Index 6.00 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 3.6 % Moisture, 37°  
Angle Slide Steel Plate  
@ 3.6 % Moisture, 27°

Apparent Cohesion PSF  
@ 3.6 % Moisture, 210  
Bulk Density PCF  
@ 0.0 % Moisture, 97.4

Angle/Repose 10" Drop  
@ 3.6 % Moisture, 35°  
Angle Internal Friction  
@ 3.6 % Moisture, 38°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Sandstone, medium grained, massive, porous, poorly cemented. Strength: Medium. RQD (Est.) 84%. DUW: 150 PCF. Ground water: Dry. Hardness: NA.

System Class: TBM, Robbins 141-127, 12' 11" dia. 32 Robbins disc cutters. RPM: 5.2. Torque: 498 ft # av. Thrust: 357 K # av. Mucking: Buckets to belt conveyor. Haulage: Gantry conveyor to rail cars. Support: Steel ring sets, 35%, roof bars and rock bolts, 10% of 4100'.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LAY-1  
Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, conglomerate, well graded cobbles to pebbles of quartzite poorly to well cemented with reddish brown sandstone.

Uniaxial Compressive Strength: NA.

RQD: (Estimated) 85%.

Dry Unit Weight: NA.

Ground Water: Dry.

Hardness: NA.

#### TUNNEL DATA:

Size: 12' 11" diameter. Grade: (+) 0.125%.

Ventilation System: 15-17 KCFM, 36" diameter pipe, 100 HP

Utility System: 3 1/2" water line, 6" air line, 8" pump line.

Water Inflow: 20-100 gpm.

Power System: 7300/480V.

Haulage System: Muck, supplies, personnel by railcar 10 ton locomotive, 10 CY cars, 24" gage 65# rail.

Support System: 4" H full rings in bad ground.

#### EXCAVATION DATA:

Machine: Robbins 141-127. Total weight: 125 tons.

Cutters: 30 Robbins steel disc, gage 6-12", center 1-11" triple disc interior 23-11".

Rotation: 5.2 RPM.

Torque: 490.7K ft. lb.

Thrust: 585.2K lb.

Muck Collection: Buckets from face, belt to rear.

Power System: 6-100 HP motors drivehead.

Guidance: Laser.

# MUCK DATA

Abrasiiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056": 0

Spec. Gravity, Material  
Size (-) 0.75": 2.65

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.00%

Plastic Limit 14.18 %

Shrinkage Limit 13.80 %

Plasticity Index 0.82 %

Toughness Index 0.21 %

Flow Index 4.00 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 3.4 % Moisture, 16°

@ 3.0 % Moisture, 15

@ 3.4 % Moisture, 32°

Angle Slide Steel Plate

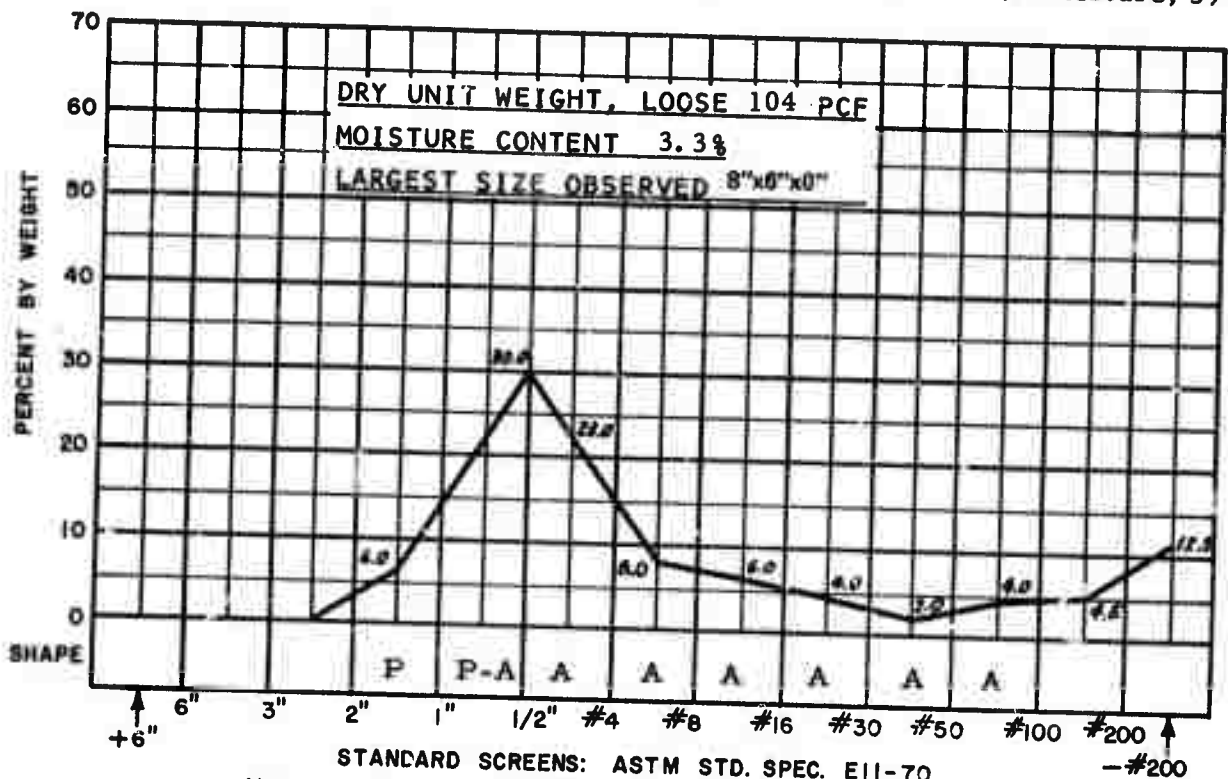
Bulk Density PCF

Angle Internal Friction

@ 3.4 % Moisture, 32°

@ 0.0 % Moisture, 88

@ 3.0 % Moisture, 39°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Conglomerate, quartzite cobbles grading to pebbles, poorly to well cemented with sandstone. Strength: NA: RQD (Est.) 85%.  
DUW: NA. Ground water: Dry. Hardness: NA.

System Class: TBM Robbins 141-127. 32 Robbins disc cutters. RPM: 5.2  
Torque: 491 K ft #. Thrust: 585 K #. Mucking: Buckets to belt.  
Haulage: Rail. Support: Rock bolts, normal, ring sets in bad ground.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. LAY-2  
Sheet 2

### ROCK DATA:

Lithology: Sedimentary, siltstone, fine grained, gray, more than 33% quartz, 30% clay, 10% feldspar, 15% mica, chlorite and gypsum.

Uniaxial Compressive Strength: 2 KPSI

RQD: (Estimated) 70%

Dry Unit Weight: 142 PCF

Ground Water: Table above tunnel but sealed off by overlying beds.

Hardness: NA

### TUNNEL DATA:

Size: 20.5' round, Grade: (+) .05%

Ventilation System: 18 KCFM exhaust 30" pipe, 60 HP.

Utility System: 6" air line, 4" pump line

Water Inflow: 50 GPH.

Power System: 4160/440V, rectified to 440 DC for head drive motors.

Haulage System: Muck, supplies, personnel, by 16 CY cars, 15 ton motor, 24" gage 70 lb rail.

Support System: Rock bolts, 8' and 10' x 3/4", set in epoxy with 5' and 13' x 16 gage pans, shotcrete placed to prevent air slacking.

### EXCAVATION DATA:

Machine: Dresser TB-205, total weight: 200 tons

Cutters: 36 Dresser steel and TCB insert discs, 32 Kennametal U43 and U44 "pick" bits. Gage: 6-#9T5TD1 TCB insert discs. Center: 6-U43TC bits mounted around a 4" chisel. Interior: 30 Type STD steel discs and 26 U44 TC bits mounted on 4 bit blocks.

Rotation: 0-6 RPM range, 5 RPM normal operating.

Torque: Maximum 879 K ft. #., normal operating 586 K ft. #.

Thrust: Maximum 1,583 K # operating 431 K #.

Anchor Pressure: Maximum 6,616 K#.

Muck Collection: Buckets from face to 36" belt to 36" belt on 140' gantry.

Power System: Four 180 HP D.C. head motors, one 75 HP for hydraulic system.

Guidance System: Laser

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-)0.056": 1.3

Spec. Gravity, Material  
Size (-)0.75": 3.13

## ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 36.80%

Plastic Limit 23.61%

Shrinkage Limit 21.04%

Plasticity Index 13.19%

Toughness Index 1.88%

Flow Index 7.00%

## MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 7.7 % Moisture, 30°

@ 7.5 % Moisture, 340

@ 7.7 % Moisture, 30°

Angle Slide Steel Plate

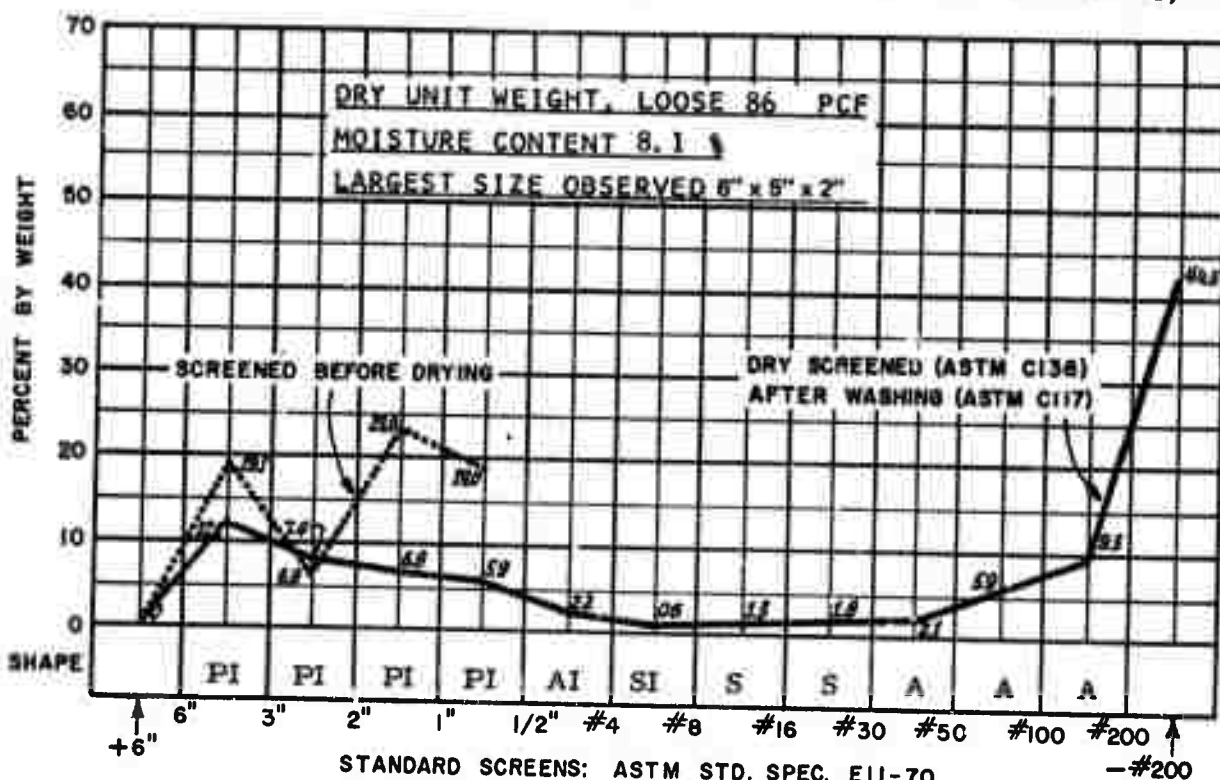
Bulk Density PCF

Angle Internal Friction

@ 7.7 % Moisture, 30°

@ 0.0 % Moisture, 98

@ 7.5 % Moisture, 36°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Siltstone, fine grained. Strength: Very low.  
RQD (Est.) 70%. DUW: 142 PCF. Ground water: Minor. Hardness: NA.

System Class: TBM, Dresser TB 205, 20.5' dia., Dresser disc cutters:  
6TCB and 30 steel, 32 Kennametal, TCB "pick" bits. RPM: 5, 586 K ft #  
Torque: 431 K # thrust. Mucking: Buckets to belt. Haulage: Rail.  
Support: Roof plates and rock bolts, at 3' or 4', continuous.

MDN STUDY

SYSTEM DATA SHEET

Ident. No. NAV-1

9/1/72

MDN

Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, sandstone, gray, medium grained, massive, friable and porous. Grains angular to subrounded, primarily quartz, poorly cemented.

Uniaxial Compressive Strength: Less than 1 KPSI, disintegrates when wet.

RQD: (Estimated) 60%

Dry Unit Weight: 117 PCF

Ground Water: Table above tunnel but sealed off by overlying beds.

Hardness: NA

#### TUNNEL DATA:

Size: 20.5' diameter. Grade: (+) .05%

Ventilation System: 18 KCFM exhaust, 30" pipe, 60 HP.

Utility System: 6" air line, 4" pump line

Water Inflow: 50 GPH.

Power System: 4160/440V, rectified to 440 DC for head drive motors.

Haulage System: Muck, supplies, personnel, by 16 CY cars, 15 ton motor, 24" gage 70 lb rail.

Support System: Rock bolts, 8' and 10' x 3/4", set in epoxy, with 5' and 13' x 16 gage pans, shotcrete placed to prevent air slacking.

#### EXCAVATION DATA:

Machine: Dresser TB-205, total weight: 200 tons

Cutters: 36 Dresser steel and TCB insert discs, 32 Kennametal U43 and U44 "pick" bits. Gage: 6-#9T5TD1 TCB insert discs. Center: 6-U43TC bits mounted around a 4" chisel. Interior: 30 Type STD steel discs and 26 U44TC bits mounted on 4 bit blocks.

Rotation: 0-6 RPM range, 5 RPM normal operating.

Torque: Maximum 879 K ft. #., normal operating 586 K ft. #.

Thrust: Maximum 1,583 K #. operating 123 K #.

Anchor Pressure: Maximum 6,616 K #.

Muck Collection: Buckets from face to 36" belt to 36" belt on 140' gantry.

Power System: Four 180 HP D.C. head motors, one 75 HP for hydraulic system.

Guidance System: Laser



# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056": 0

Spec. Gravity, Material  
Size (-) 0.75": 2.72

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.20%

Plastic Limit 16.91%

Shrinkage Limit 16.60 %

Plasticity Index 1.29 %

Toughness Index 0.28 %

Flow Index 4.50 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 8.6 % Moisture, 31°

@ 8.1 % Moisture, 45

@ 8.6 % Moisture, 28°

Angle Slide Steel Plate

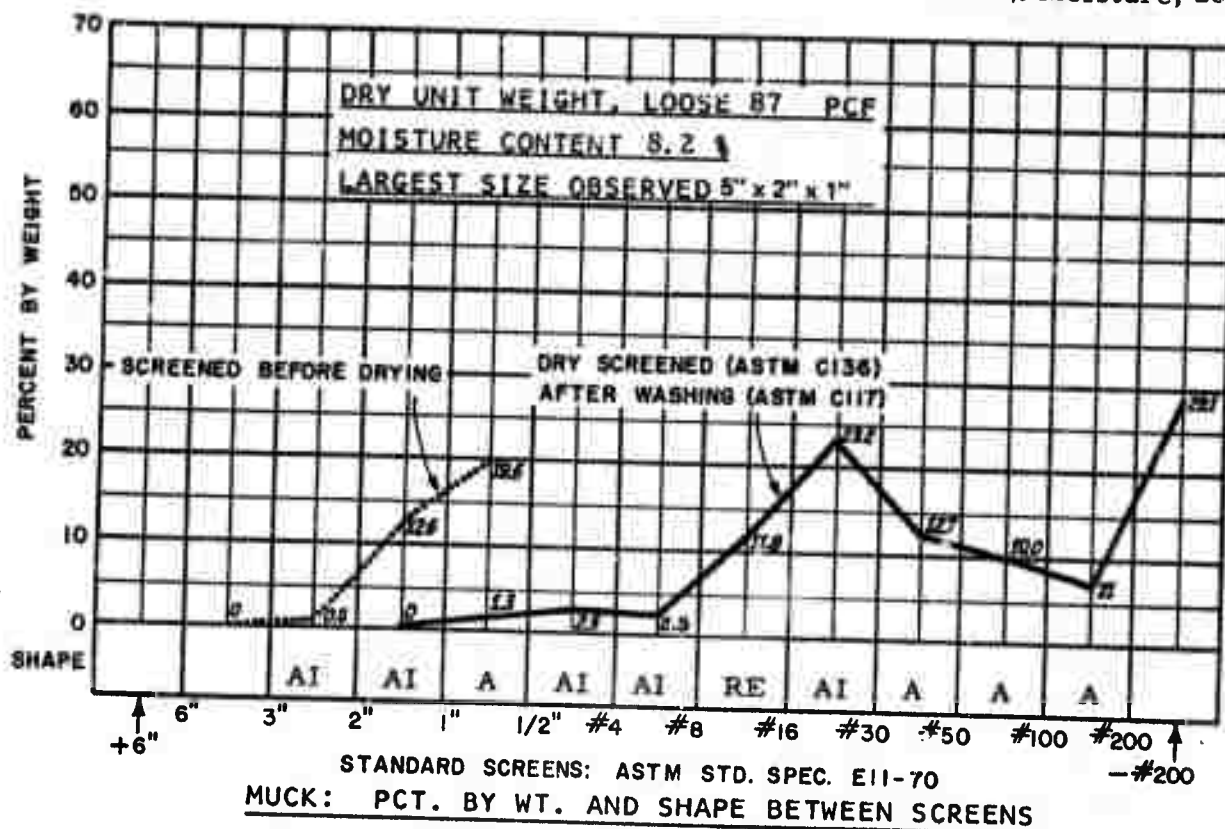
Bulk Density PCF

Angle Internal Friction

@ 8.6 % Moisture, 32°

@ 0.0 % Moisture, 99

@ 8.1 % Moisture, 28°



## SUMMARY

Rock Class: Sedimentary: Sandstone, massive, friable, porous, medium grained. Very low strength. RQD (Est.) 60%. DUW: 117 PCF. Ground water: Minor. Hardness: NA.

System Class: TBM, Dresser TB 205, 20.5' dia. Dresser, disc cutters 6TCB and 30 steel, 32 Kennametal, TCB "pick" bits. RPM: 5, 586 K ft # torque, 123 K # thrust. Mucking: Buckets to belt. Haulage: Rail. Support: Roof plates and rock bolts, at 3' or 4', continuous.

MDN STUDY

SYSTEM DATA SHEET  
MDN

Ident. No. NAV-2  
Sheet 2

0/1/72

### ROCK DATA:

Lithology: Sedimentary, sandstone, fine grained, brown to dark red massive.  
Uniaxial Compressive Strength: NA.  
RQD: 60%.  
Dry Unit Weight: NA.  
Ground Water: Generally dry.  
Hardness: NA.

### TUNNEL DATA:

Size: 18' 4" diameter. Grade: +.045%.  
Ventilation System: 22 KCFM, exhaust, 48" diameter pipe, 2-150 HP  
Utility System: 8" air line, 4" water line, 8" pump line.  
Water Inflow: 40 gpm.  
Power System: 13200/440V.  
Haulage System: Muck, supplies, personnel by railcars, 15 ton locomotive  
10 CY cars, 36" gage, 50# rail.  
Support System: Rock bolts, 5', 6', 8' x 5/8", 24" centers, 14 gauge pans  
12' 6" or 8' 6" x 8".

### EXCAVATION DATA:

Machine: Lawrence HRT. Total weight: NA.  
Cutters: 32 Lawrence Mfg Tungsten Carbide Button, roller, disc and tricone.  
Gage: 5 TCB roller, Interior 24 disc and 2 TCB roller, center 1-24"  
TCB tricone.  
Rotation: Head 11 RPM, center 30 RPM.  
Torque: Center cutter 150 HP, head 750 HP, 364K ft. lb.  
Thrust: 492K lbs.  
Muck Collection: Buckets from face discharging to 24" belt.  
Power System: Electro-Hydraulic. Total HP: 960  
Guidance System: Laser

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size NA :

Spec. Gravity, Material  
Size NA :

## ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %

Plastic Limit NA %

Shrinkage Limit NA %

Plasticity Index NA %

Toughness Index NA %

Flow Index NA %

## MATERIAL SIZE

IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ % Moisture, NA

@ % Moisture, NA

@ % Moisture, NA

Angle Slide Steel Plate

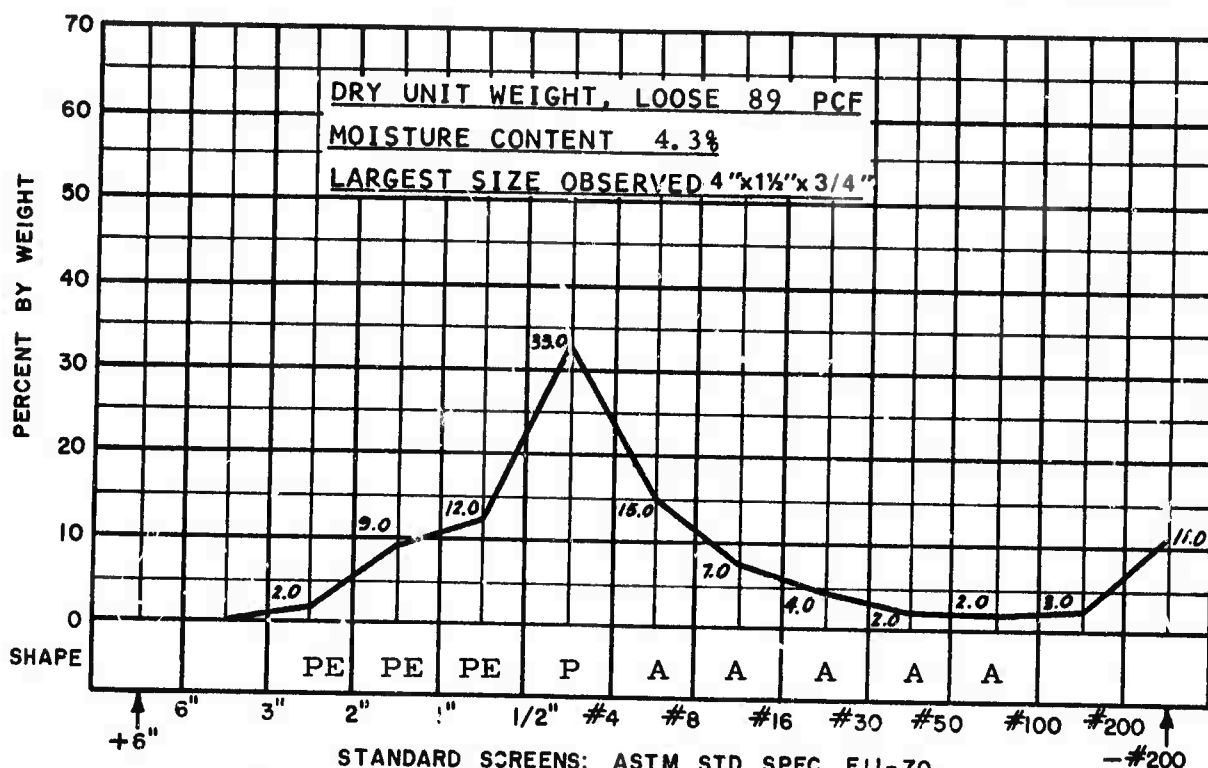
Bulk Density PCF

Angle Internal Friction

@ % Moisture, NA

@ % Moisture, NA

@ % Moisture, NA



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Sandstone, fine grained, massive. Strength: NA.  
RQD: 60%. DUW: NA. Ground water: Dry. Hardness: 32, schmidt.

System Class: TBM Lawrence HRT 18' 4" dia. 32 Lawrence button roller, disc cutters. 11 RPM head, 30 RPM center. 364 K ft # torque. 492 K # thrust.  
Mucking: Buckets to belt. Haulage: Rail. Support: Rock bolts 24" centers.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. RO-1

Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, sandstone, coarse grained, poorly consolidated, arkosic, with minor layers of thin seamed siltstone.  
Uniaxial Compressive Strength: 50 to 150 PSI dry-disintegrates when wet.  
RQD: (Estimated) 30%.  
Dry Unit Weight: 125 PCF.  
Ground Water: Saturated when first opened.  
Hardness: NA

#### TUNNEL DATA:

Size: 10' high by 8' wide, rectangular. Grade (+) 1/2%.  
Ventilation System: 5 to 7 KCFM, pressure, 18" dia. vent tube.  
Utility System: 4" airline.  
Water Inflow: 20-25 gpm.  
Power System: 440/110V, trailing cable.  
Haulage System: Muck, personnel and supplies by rail cars, 24" gage, 40# rail.  
Support System: None, rock bolts and/or shotcrete in bad ground.

#### EXCAVATION DATA:

Machine: Alpine Miner, Type F6-A. Total Weight: 11 tons.  
Cutters: 72, Kennametal U43K, Carbide tipped, "pick" type. Cutters; mounted on twin ripper heads, rotating about a horizontal axis at 90° to a boom which moves the heads vertically and horizontally.  
Rotation: 60 RPM, motor and gear box integral with boom.  
Torque: 50.4 HP  
Thrust: Sumping thrust from crawler motors, 2 @ 20.4 HP. Vertical and horizontal by hydraulic cylinders powered by a 10.4 HP electro-hydraulic system.  
Anchor Pressure: Crawlers only.  
Muck Collection: Central 14" chain conveyor, fed by gathering arms, discharges on an 18" x 30' belt feeding 116' of 20" Serpentix conveyor. Transverse folds are molded into 20" x 8" long rubber Serpentix sections, which are bolt connected at reinforced flanges connected to an endless chain driven by a sprocket. Folds allow inside edge to compress and outside to expand on curves. Vertebral side rail sections, alternating with straight sections, are supported by wheeled gantry legs riding a 60" gage track, under which cars are spotted.  
Power System: 440V, trailing cable.  
Guidance System: Transit/Laser.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. WNG-1  
Sheet 1

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056": 0

Spec. Gravity, Material  
Size (-) 0.75": 2.71

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 24.90 %  
Plasticity Index 4.93 %

Plastic Limit 19.97 %  
Toughness Index 0.66 %

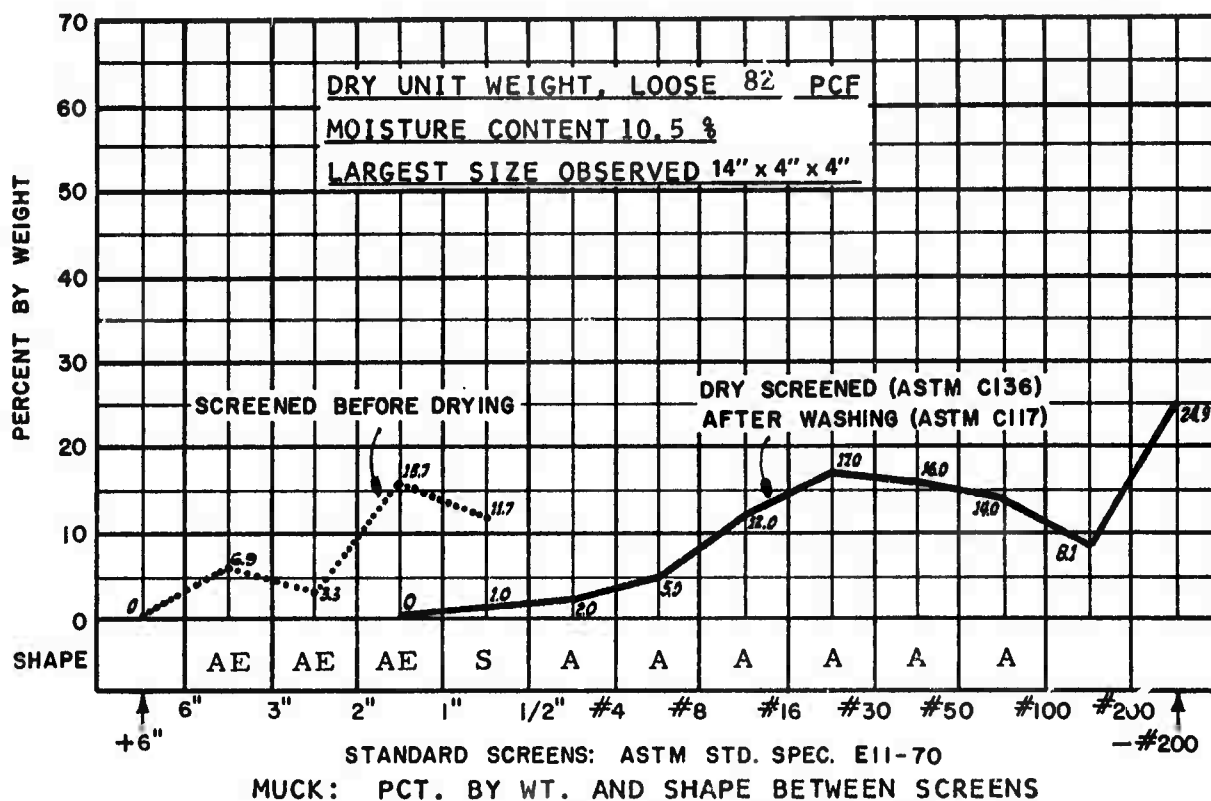
Shrinkage Limit 19.94 %  
Flow Index 7.40 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop  
@ 10.1 % Moisture, 34°  
Angle Slide Steel Plate  
@ 10.0 % Moisture, 32°

Apparent Cohesion PSF  
@ 10.6 % Moisture, 0  
Bulk Density PCF  
@ 0.0 % Moisture, 85

Angle/Repose 10" Drop  
@ 10.1 % Moisture, 31°  
Angle Internal Friction  
@ 10.6 % Moisture, 27°



## SUMMARY

Rock Class: Sedimentary: Sandstone, coarse grained, poorly consolidated, arkosic, minor thin seamed siltstone. Very low strength. RQD (Est.) 30%.  
DUW: 125 PCF. Ground water: Saturated. Hardness: NA.

System Class: TBM, Alpine F6A, twin head, 10' high x 8' heading. 72 Kennametal TCB pick type bits. 60 RPM, 50.4 HP head torque, 10.4 HP boom power, 40.8 HP sumping thrust. Mucking: Gathering arms-flight conveyor. Haulage: Elevating conveyor - Serpentix conveyor on gantry - rail cars. Support: Normally none.

MDN STUDY

SYSTEM DATA SHEET

Ident. No. WNG-1

9/1/72

MDN

Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, sandstone, coarse grained, poorly consolidated, arkosic, with minor layers of thin seamed siltstone, varying concentrations of replacement silica.

Uniaxial Compressive Strength: 50 to 150 PSI dry-disintegrates when wet.

RQD: (Estimated) 30%

Dry Unit Weight: 125 PCF

Ground Water: Saturated when first opened.

Hardness: NA

#### TUNNEL DATA:

Size: 5' wide x 9' high, nominally rectangular. Grade: Varies.

Ventilation System: 5 to 7 KCFM, pressure, 18" vent tube.

Utility System: 2" air, 1" waterline.

Water Inflow: 20-25 gpm when levels are first opened; generally dry after drainage.

Power System: None in development headings, 440V to scraper hoists, 110V lighting.

Haulage System: Muck is scraped from the face of a cross cut to a slusher drift, cross scraped to a muck raise, and loaded into 4 cu. ft. rocker dump rail cars on main level about 80' below. Scrapers are 42", hoists 15 HP. Personnel access by ladder, supplies by rail cars and air-powered hoists through raises.

Support System: None. Rockbolts in bad ground.

#### EXCAVATION DATA:

Conventional Scraper-Rail Haulage System.

Drilling: LeRoi Model 35 jackhammers mounted on 6' airfeed legs.

Drill Round: Five hole box or vertical line burn cut, 6' depth, included in 18 hole round, all holes 1 1/2" diameter.

Explosives: 50# Dupont 40% Galex #2, Powder factor: 5#/cu. yd.

Blasting: Safety fuse and caps.

Mucking System: 42" Scrapers, 15 HP hoists.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056": 0

Spec. Gravity, Material  
Size (-) 0.075": 2.72

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 25.25%

Plastic Limit 24.74%

Shrinkage Limit 23.37 %

Plasticity Index 0.51 %

Toughness Index 0.13 %

Flow Index 4.00 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 9.0 % Moisture, 32°

@ 9.0 % Moisture, 0

@ 9.0 % Moisture, 31°

Angle Slide Steel Plate

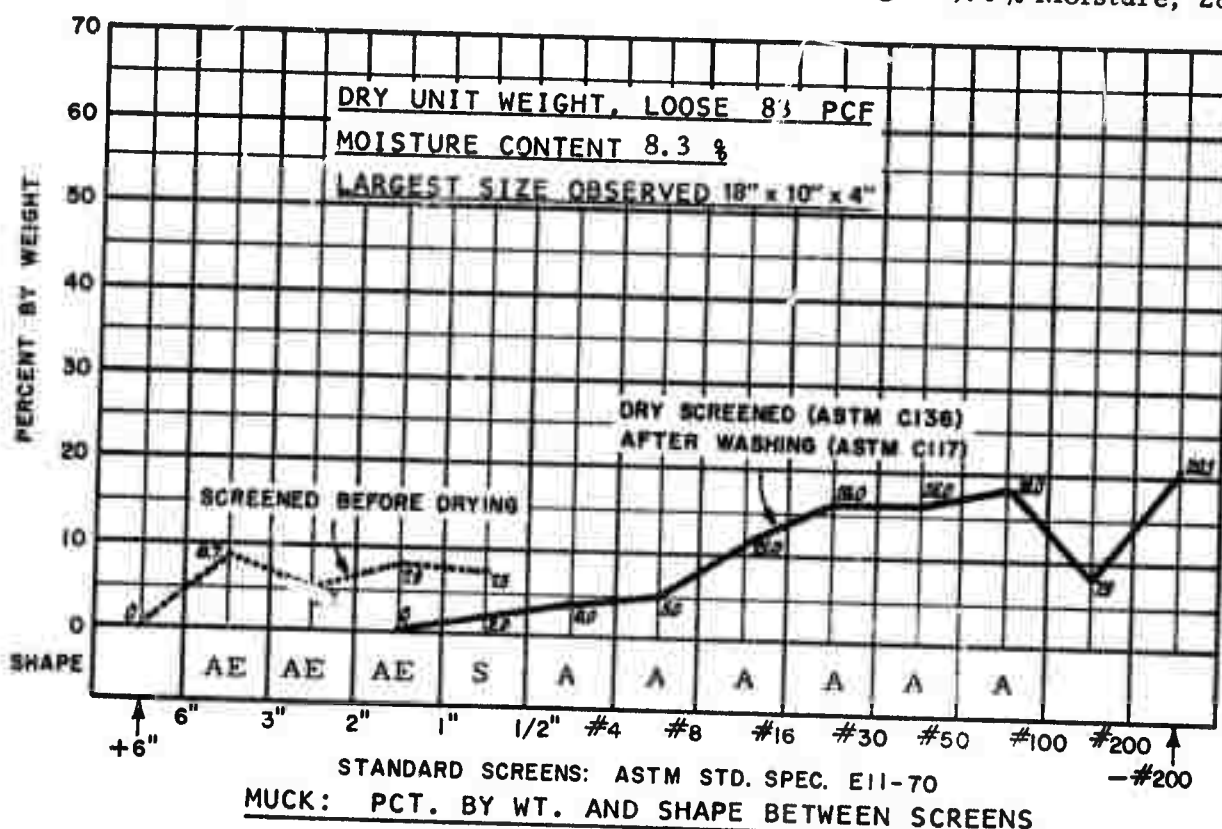
Bulk Density PCF

Angle Internal Friction

@ 9.0 % Moisture, 40°

@ 0.0 % Moisture, 86

@ 9.0 % Moisture, 28°



## SUMMARY

**Rock Class:** Sedimentary: Sandstone, coarse grained, poorly consolidated, arkosic, minor thin seamed siltstone, varying replacement silica. Very low strength. RQD (Est.) 30%. DUW: 125 PCF. Ground water: Saturated.

**Hardness:** NA.

**System Class:** Conventional Scraper-Rail. 5' wide x 9' high, rectangular. Airleg jackhammer, 18 - 6' holes, burn cut. PF 5#/CY. Mucking: Scraper to raise. Haulage: Rail cars - skip to surface. Support: Normally none.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. WNG-2  
Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, sandstone, arkosic, irregularly bedded, loosely consolidated with layers and lenses of silty mudstone.  
Uniaxial Compressive Strength: Less than one KPSI.  
RQD: (Estimated) 15%  
Dry Unit Weight: 113 PCF  
Ground Water: Saturated; water table above tunnel, heading is drained in advanced by lateral pilot holes in ribs.  
Hardness: NA

#### TUNNEL DATA:

Size: 21 ft., diameter. Grade: (+) 0.2%.  
Ventilation System: 20 KCFM, 36" pipe, pressure at face, exhaust in access.  
Utility System: 6" air line, 6" pump line.  
Water Inflow: 200 gpm.  
Power System: 4160/480V.  
Haulage System: Muck, personnel, supplies by rail cars.  
Support System: Continuous, precast concrete rings 8" and 10" thick, erected in four-4' segments.

#### EXCAVATION DATA:

Shield: Robbins 221S ripper, Total weight: 285 tons  
Thrust: 3,500 tons total.  
Muck Collection System: Muck is ripped from the face by a ripper tooth and drawn through the shield to a 6' conveyor by hydraulic ram with a bucket opposite the ripper tooth.  
Power System: Hydraulic.  
Guidance System: Laser



# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-)0.065" : 0

Spec. Gravity, Material  
Size (-)0.185": 2.86

## ATTERBERG LIMITS, MATERIAL SIZE (-)0.185 IN.

Liquid Limit 17.75%

Plastic Limit 16.19%

Shrinkage Limit 13.94 %

Plasticity Index 1.56 %

Toughness Index 0.27 %

Flow Index 5.8 %

## MATERIAL SIZE (-)0.185IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 14.3 % Moisture, 38°

@ % Moisture, NA

@ 14.3 % Moisture, 33°

Angle Slide Steel Plate

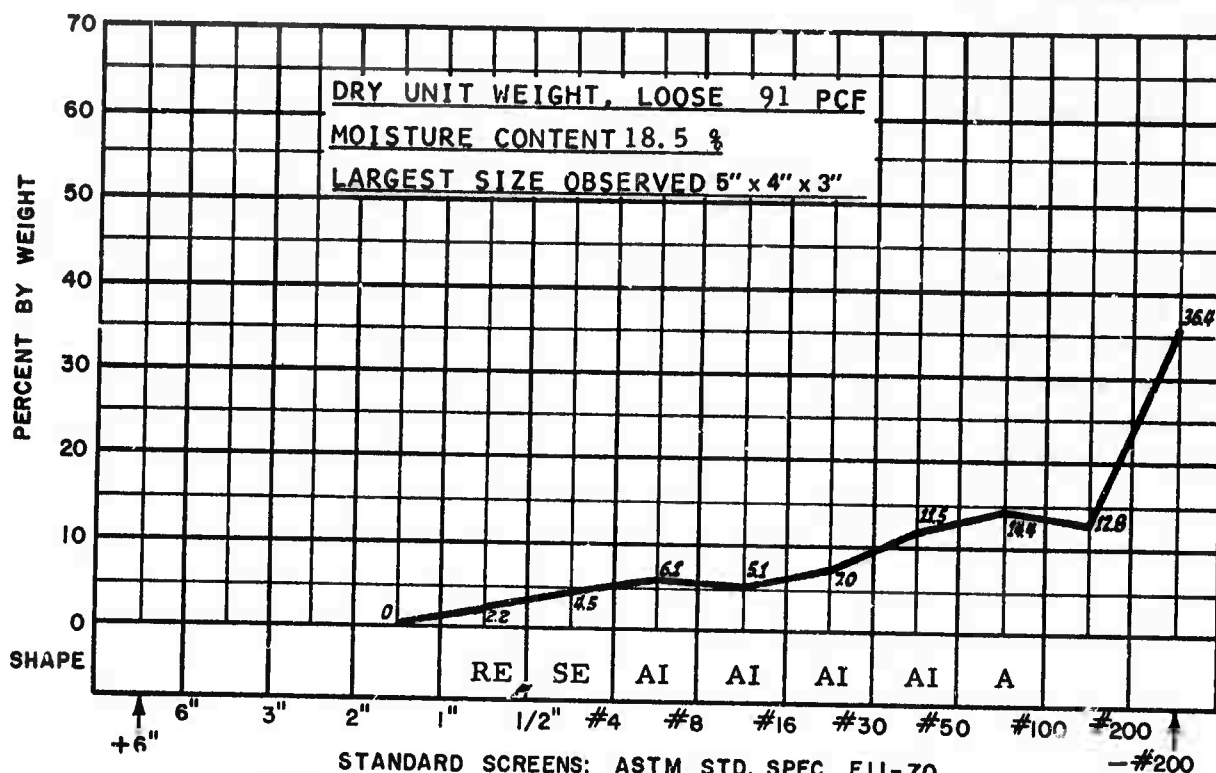
Bulk Density PCF

Angle Internal Friction

@ 12.5 % Moisture, 36°

@ % Moisture, NA

@ 13.0 % Moisture, 42°



STANDARD SCREENS: ASTM STD. SPEC. E11-70  
MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

## SUMMARY

Rock Class: Sedimentary: Sandstone, arkosic, loosely consolidated, with layers and lenses of silty mudstone. Strength: Very low. RQD (Est.) 15%.  
DUW: 113 PCF. Ground water: Saturated. Hardness: NA.

System Class: Shield, Robbins 221S ripper, 21' dia. Thrust: 3500 tons.  
Mucking: Hydraulic boom operated bucket scraper to conveyor. Haulage: Rail.  
Support: Continuous, precast concrete ring segments.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. SF-1  
Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, sandstone, biotite rich siltstone,  
poorly to well consolidated, poorly to well sorted.  
Uniaxial Compressive Strength: 2 KPSI  
RQD: (Estimated) 50%  
Dry Unit Weight: 142 PCF  
Ground Water: Sandstone saturated, water table above tunnel, heading  
drained in advanced by lateral pilot holes in ribs.  
Hardness: NA

#### TUNNEL DATA:

Size: 21 ft., round, Grade: (+) 0.2 pct.  
Ventilation System: 20 KCFM, 36" pipe, pressure at face, exhaust in  
access.  
Utility System: 6" air line, 6" pump line.  
Water Inflow: 20 gpm  
Power System: 4160/480V  
Haulage System: Muck, personnel, supplies by rail cars.  
Support System: Continuous, precast concrete rings 8" and 10" thick,  
erected in four 4' segments.

#### EXCAVATION DATA:

Shield: Robbins 221S ripper, total weight: 285 tons.  
Thrust: 3,500 tons total.  
Muck Collection System: Muck is ripped from face by a ripper tooth and  
drawn through the shield to a 6' conveyor by hydraulic ram with a bucket  
opposite the ripper tooth.  
Power System: Hydraulic  
Guidance System: Laser

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-)0.056": 0

Spec. Gravity, Material  
Size (-)0.075": 3.02

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 31.5 %

Plastic Limit 26.8 %

Shrinkage Limit 21.5 %

Plasticity Index 4.7 %

**Toughness Index 0.61 %**

Flow Index 7.6 %

MATERIAL SIZE (-)1.0 IN.

Angle/Repose 1" Drop  
@ 15.1 % Moisture, 38°

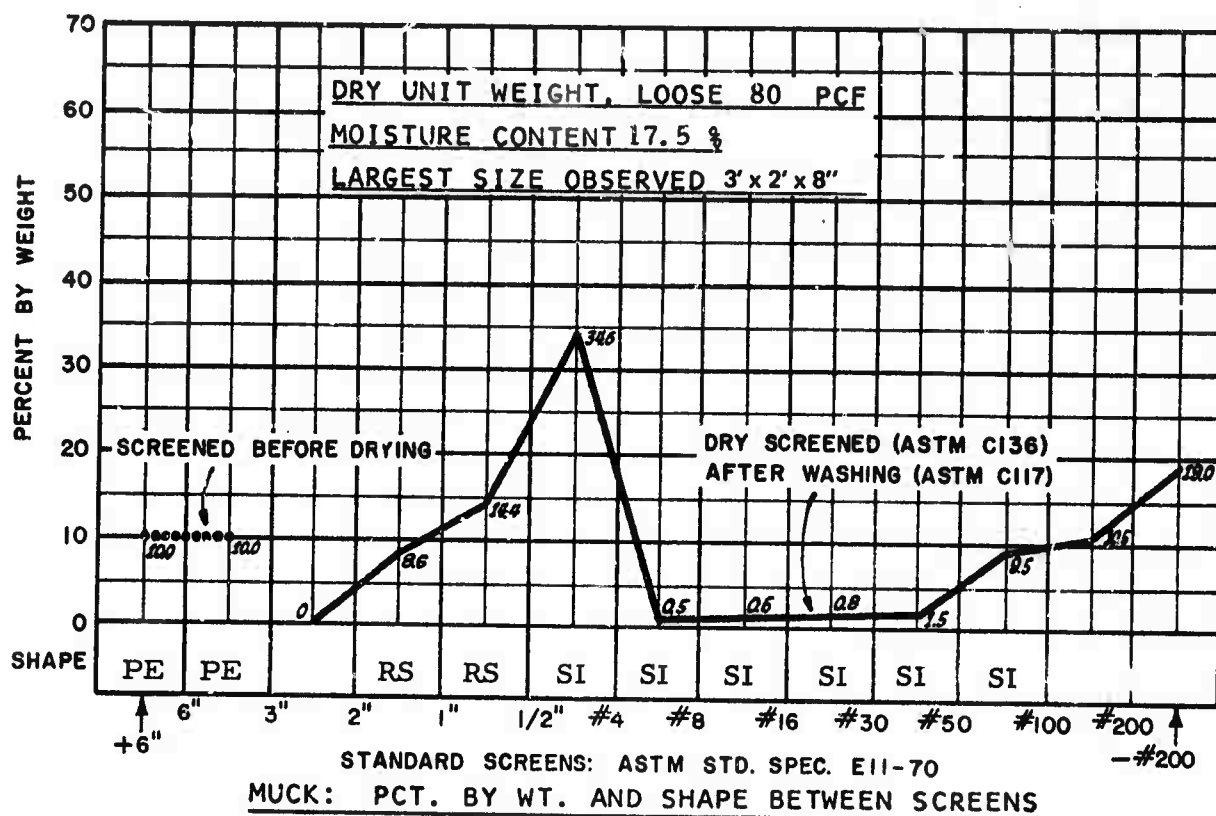
Apparent Cohesion PSF  
@ % Moisture, NA

Angle/Repose 10" Drop  
@ 15.1 % Moisture, 36°

Angle Slide Steel Plate  
@ 15.1 % Moisture, 30°

Bulk Density PCF  
@ % Moisture, NA

Angle Internal Friction  
@ 15 % Moisture, 27°



## SUMMARY

Rock Class: Sedimentary: Sandstone and siltstone, poorly to well consolidated. Strength: Very low. RQD (Est.) 50%. DUW: 142 PCF. Ground water: Saturated. Hardness: NA.

System Class: Shield, Robbins 221S ripper, 21' dia. Thrust 3500 tons.

Mucking: Hydraulic boom operated bucket scraper to conveyor. Haulage: Rail.  
Support: Continuous, precast concrete ring segments.

MDN STUDY  
9/1/72

SYSTEM DATA SHEET  
MDN

Ident. No. SF-2  
Sheet 2

#### ROCK DATA:

Lithology: Sedimentary, mudstone, dark gray, fine grained, massive.  
Uniaxial Compressive Strength: 11 KPSI dry.  
RQD: (Estimated) 90%.  
Dry Unit Weight: 144 PCF.  
Ground Water: Generally dry.  
Hardness: NA

#### TUNNEL DATA:

Size: 10' high x 9' wide (7'-6" top, 9'-6" bottom). Grade: (+) 1/2%.  
Ventilation System: 5 KCFM, exhaust from face, pressure to venthole, 16" flexhaust, 24" vent tube, 2-25 HP Axivane fans.  
Power System: 440V trailing cable.  
Haulage System: Muck, personnel and supplies by rail cars, 36" gage, 45# rail.  
Support: 4" WF steel sets at 3' or 6'.

#### EXCAVATION DATA:

Machine: Alpine Miner, Type F6-A. Total Weight: 11 tons.  
Cutters: 40 Kennametal U43KH, Carbide tipped, "pick" type. Cutters mounted on twin ripper heads, rotating about a horizontal axis at 90° to a boom which moves heads vertically and horizontally.  
Rotation: 78 RPM, motor and gear box integral with boom.  
Torque: 50.4 HP.  
Thrust: Sumping thrust from crawler motors, 2 @ 20.4 HP, vertical and horizontal by hydraulic cylinders powered by a 10.4 HP electro-hydraulic system.  
Anchor Pressure: Crawlers only.  
Muck Collection: Central 14" flight conveyor fed by two gathering arms mounted on an inclined apron, discharges on an 18" elevating conveyor loading rail cars.  
Power System: 440V, trailing cable.  
Guidance System: Transit/Laser.

# MUCK DATA

Abrasiveness  
N. A.

Pot. Vol. Change, Material  
Size (-) 0.056": 0

Spec. Gravity, Material  
Size (-) 0.75": 2.87

## ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 28.30%

Plastic Limit 24.97 %

Shrinkage Limit 19.12 %

Plasticity Index 3.33 %

Toughness Index 0.92 %

Flow Index 3.60 %

## MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ 12.7 % Moisture, 29°

@ 10.9 % Moisture, 37

@ 12.7 % Moisture, 28°

Angle Slide Steel Plate

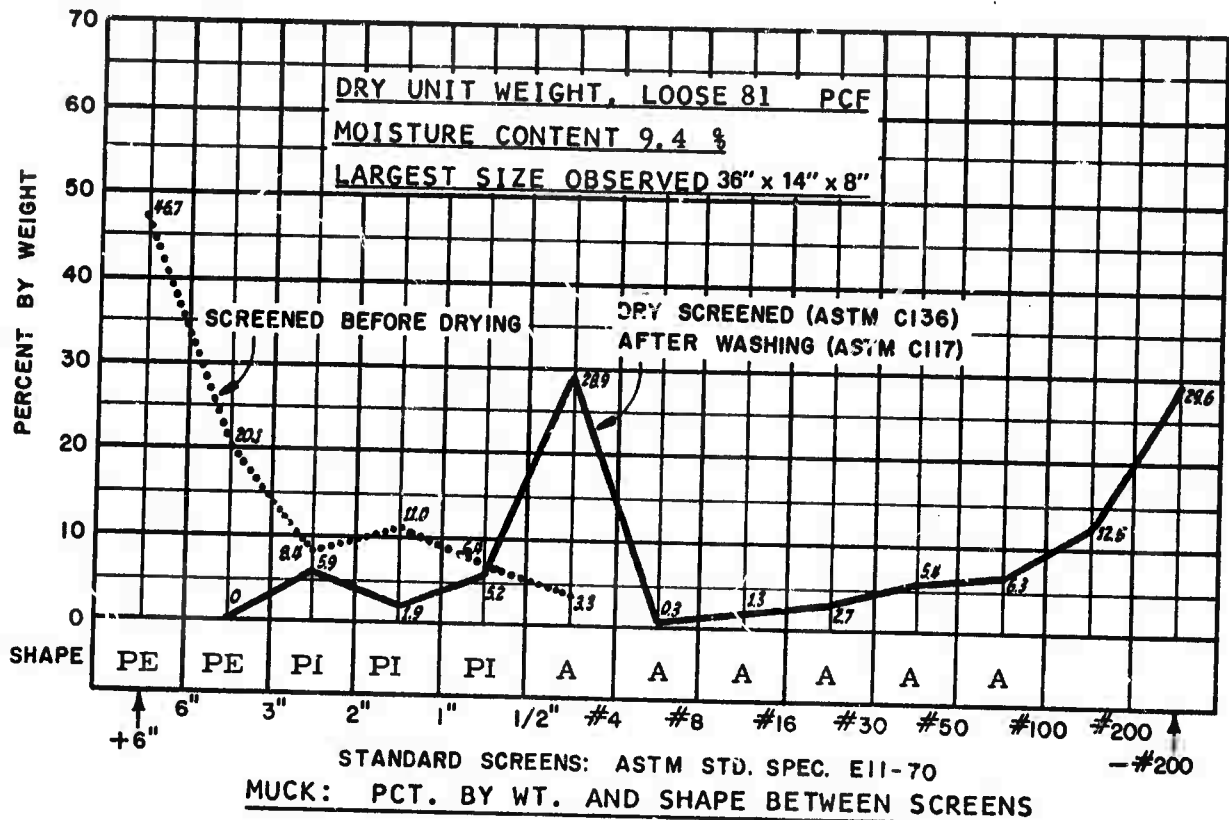
Bulk Density PCF

Angle Internal Friction

@ 12.7 % Moisture, 31°

@ 0.0 % Moisture, 79

@ 10.9 % Moisture, 35°



## SUMMARY

Rock Class: Sedimentary: Mudstone ("shale") fine grained, massive.  
Medium strength. RQD (Est.) 90%. DUW: 144 PCF. Ground water: Dry.  
Hardness: NA

System Class: TBM, Alpine F6A, twin head, 10' high x 9' heading. 40 Kernametal  
TCB pick type bits. 78 RPM, 50.4 HP head torque, 10.4 HP boom power, 40.8  
HP sumping thrust. Mucking: Gathering arms - flight conveyor. Haulage:  
Elevating conveyor-rail cars. Support: Steel sets at 3' or 6', continuous.

MDN STUDY

SYSTEM DATA SHEET  
MDN

Ident. No. KM-1  
Sheet 2

9/1/72

## APPENDIX D

### ALGORITHM DEVELOPMENT

In simple regression, it is supposed that with each observation value, there is another quantity which can be observed or somehow related to the observation. After  $n$  observations, there exists a series of pairs,  $(x_1, y_1)$ ,  $(x_2, y_2)$ ,  $\dots$ ,  $(x_n, y_n)$ . The question we wish to answer is to determine if there is a relationship between  $y$  and  $x$  and how this relationship can be obtained.

One may assume that there is such a relationship, and that this relationship is linear. With this assumption, one may write

$$y = \alpha x + \beta \quad (1)$$

The  $x_i$ ,  $i = 1, \dots, n$ , are the values of the independent variable  $x$ , and the  $y_i$ ,  $i = 1, \dots, n$ , are the values of the dependent variable  $y$ .  $\alpha$  and  $\beta$  are the coefficients which will have to be determined from the observation points.

It is possible that a relationship exists between  $x$  and  $y$ , but the relationship is not linear. A possible alternate in this case is to find another variable,  $x^1$ , related to  $x$ , such that  $y$  can then be linearly related to  $x^1$ . The new variable  $x^1$  will then be used in place of  $x$  in the discussions that follow.

Assuming that the linear relationship is valid, we can create an error term which is the sum of the squares of all deviations of observed values from the linear Equation (1). Thus the error  $\epsilon$  is

$$\epsilon = \sum_{i=1}^n (y_i - (\alpha x_i + \beta))^2 \quad (2)$$

and determine  $\alpha$  and  $\beta$  so  $\epsilon$  is minimum. This simple regression is known as the method of "least squares". The solution can be shown to be:

$$\alpha = v_{xy} / s_x^2 \quad (3)$$

$$\beta = \bar{y} - \alpha \bar{x} \quad (4)$$

where

$$s_x^2 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2 \quad (5)$$

$$v_{xy} = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y}) \quad (6)$$

$\bar{x}$  and  $\bar{y}$  are the arithmetic averages of the  $x_i$  and  $y_i$  respectively.

Equations (3) and (4) give the necessary coefficients in terms of observed values for the predictor Equation (1). If  $y$  had been the MDN, and  $x$  an in-situ rock property (or some transformation of it), then this simple regression would have resulted in a predictor equation for the MDN.

A procedure similar to the simple regression technique will be applicable if we want to relate a dependent variable  $y$  to several independent variables  $x_1, x_2, x_3, \dots, x_{m-1}$ . (Note the  $x_1, x_2, \dots, x_{m-1}$  are independent variable and not the observation points themselves). If  $n$  observations are taken, then one has the following sets of points:

$(y_1, x_{1,1}, x_{2,1}, x_{3,1}, \dots, x_{m-1,1}), (y_2, x_{1,2}, x_{2,2}, x_{3,2}, \dots, x_{m-1,2}), \dots, (y_n, x_{1,n}, x_{2,n}, x_{3,n}, \dots, x_{m-1,n})$ .

A linear relationship is assumed to exist between  $y$  and  $x_1, x_2, \dots, x_{m-1}$ . Thus, one has

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \dots + \alpha_{m-1} x_{m-1} \quad (7)$$

The coefficients  $\alpha_0, \alpha_1, \dots, \alpha_{m-1}$  will have to be determined from the  $n$  observations of the variables.

To solve for the coefficients requires the manipulation of certain arrays. Defining the following one dimensional arrays:

$$\alpha = \begin{pmatrix} \alpha_0 \\ \alpha_1 \\ \vdots \\ \alpha_{m-1} \end{pmatrix} ; \quad w = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix} \quad (8)$$

Let A be the two-dimensional array.

$$A = \begin{pmatrix} 1 & x_{1,2} & x_{2,1} & \cdots & x_{m-1,1} \\ 1 & x_{1,2} & x_{2,2} & \cdots & x_{m-1,2} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & x_{1,n} & x_{2,n} & \cdots & x_{m-1,n} \end{pmatrix} \quad (9)$$

Define a vector error by:

$$z = w - A\alpha \quad (10)$$

The scalar error is:

$$\begin{aligned} \epsilon &= z^T z = [w - A\alpha]^T [w - A\alpha] \\ &= \alpha^T A^T A \alpha - (w^T A \alpha + \alpha^T A^T w) + w^T w \end{aligned} \quad (11)$$

The derivative with respect to  $\alpha$  is:

$$\frac{d\epsilon}{d\alpha} = 2A^T A \alpha - 2A^T w \quad (12)$$

For minimum error,  $d\epsilon/d\alpha = 0$ , thus

$$\alpha = (A^T A)^{-1} A^T w \quad (13)$$

$A^T$  is the transpose of the matrix A given by Equation (9).

The general computational procedure is as follows:

- (1) Form the array A as given by Equation (9).
- (2) Obtain the transpose,  $A^T$ , from A. This is just a matter of interchanging rows and columns.
- (3) Compute  $A^T A$ , then  $(A^T A)^{-1}$ , then  $(A^T A)^{-1} A^T$ . This involves a series of matrix multiplications and matrix inversion. These techniques are readily available from a computer.
- (4) Form the array w from Equation (8).



- (5) Multiply the result of Step (3) by the result of Step (4). This yields a set of coefficients  $\alpha_0, \alpha_1, \dots, \alpha_{m-1}$ .
- (6) Test for goodness of fit or the quality of the predictor equation.

A basic assumption is that the predictor equation is linear, and that the independent variables to use are the observation variables themselves. It may be necessary to define another set of variables  $x_1', x_2', \dots, x_{m-1}'$  to use in order to obtain a linear relationship.

It often happens that the independent variables are themselves related. If a linear relationship exists between any two of the independent variables,  $(A^T A)^{-1}$  will be singular, i.e.,  $A^T A$  will have zero determinant, and hence  $(A^T A)^{-1}$  cannot be computed. If this is so,  $\alpha$  is difficult to compute, and the standard errors of the calculated coefficients are huge, giving an inaccurate predictor equation. This problem can be circumvented by performing the regression analysis with one variable, then with two variables, etc. while being careful when this problem arises. One may combine linearly any two variables that are highly correlated and use the combined variable as in the independent variable.

Good computer routines exist which are available on most computers, including routines for matrix transpose, matrix multiplication and matrix inversion, together with standard routines to compute means and standard deviations of a set of observations. In fact, there also exists software that performs stepwise regression analysis, performing the above calculations plus multiple correction coefficients and residuals.

In multiple regression to predict an MDN, the MDN is treated as the dependent variable. The set of independent variables may include the following in situ rock properties.

- (a) Rock classification, quantified, e.g., as Igneous = 1, Metamorphic = 2, Sedimentary = 3
- (b) Compressive strength,  $F_c$
- (c) Rock quality designation, RQD
- (d) Dry Unit Weight, DUW
- (e) Hardness, H
- (f) Ground Water, GW quantified, e.g., as Dry = 1, Minor = 2, Wet = 3

Additional parameters peculiar to the excavation method may also be included in the set of independent variables. Some of these variables may be excluded from the analysis; others still undefined may be included. The regression analysis may be performed using one or more of these variables.

A set of observations is obtained, and with each set of observations, an MDN is indicated. A table with the following entries will be created:

<u>MDN</u>	<u>CLASS</u>	<u>Fc</u>	<u>RQD</u>	<u>DUW</u>	<u>H</u>	<u>GW</u>
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____

It is seen that  $y$  corresponds to MDN, and CLASS, Fc, RQD, DUW, H, and GW, correspond to  $x_1$ ,  $x_2$ , . . . , and  $x_3$ , respectively. The matrix in Equation (9) corresponds to the observation points. The array in Equation (8) corresponds to the MDN indicated in column 1. The predictor equation may be obtained from Equation (13):

Several iterations of this analysis should be performed on the computer in order to determine which variable or combinations of variables are appropriate to include in the predictor equation. Certain tests can be performed to determine the quality and accuracy of this predictor equation. With computer routines readily available, several iterations may be performed with reasonable cost and in a very short time.

## APPENDIX E

### TRANSPORT SYSTEM SELECTION PARAMETERS

The following list of equipment capabilities, system constraints, and MDN applications is taken in part from Report No. FRA-RT-71-57, "Materials Handling for Tunnels," HN-8080, Holmes & Narver, Inc., and Resource Management Corporation, September 1970, prepared for the U. S. Department of Transportation, Washington, D. C., with additional details provided by the authors. With some differences, the list was incorporated as Section 3.6 of the Annual Technical Report of the first year's program. MDN applicability is based only on muck characteristics, and is subject to constraints imposed by such factors as tunnel size, grade and length, equipment and power cost and availability, and environmental considerations.

#### UNITIZED SYSTEMS

##### Conventional Rail Systems

##### Capabilities and Advantages

Hauling capacities can be varied by the addition or removal of cars or trains.

Materials, supplies, and personnel can be transported by the system.

Easily adaptable to automatically controlled operation.

Loading and dumping can be done rapidly.

Track extension is relatively simple.

##### System Constraints

A large percentage of tunnel cross section is occupied by equipment.

High speeds needed for short cycle time.

Ideal road bed and track conditions are necessary if delays cannot be tolerated.

Passing tracks are required in long tunnels.

A secondary system or assisted haulage is needed if vertical grade is over 4 percent.

Supply of materials required for system extension is a major operation at high advance rates.

Small clearances, high speeds, and massive moving equipment combine to produce long delays and serious injuries in event of accidents.

Combustion products complicate ventilation unless vehicles are powered electrically.

#### Applicability

Applicable to any of the MDN's so far developed. Special cars would be required for high speed operations with very wet muck, and special dumping facilities with MDN's 6 and 7.

#### Siderail Systems

##### Capabilities and Advantages

Hauling capacities can be varied by the addition or removal of units.

Materials, supplies, and personnel can be transported by the system.

Automatically controlled operation.

Loading and dumping can be done rapidly.

Can be used on much steeper grades than conventional rail systems.

Vertical and horizontal guidance tends to reduce frequency of derails and other accidents.

##### System Constraints

Power units for siderail systems require electrical bus bars to be extended with the track.

The small size of units in current use limits haulage capacity, and the number of power units can result in maintenance problems and delays.

Continuous bus bars may be a personnel hazard.

#### Applicability

MDN's 1 through 7 could be transported by this system. Problems in unloading cars can be expected from MDN's 6 and 7 if wet, due to the high percentage of fines.

## Free Vehicles

### Capabilities and Advantages

System capacity can be varied by the number of vehicles or by change in speed.

Materials can be transported inbound and outbound.

Guideway for operation is not required.

### System Constraints

Tunnel size limits use of free vehicles in small tunnels unless turnouts are provided.

Roadway must be well graded and maintained to support weight and speed of vehicles.

Present design of vehicles uses excessive amounts of tunnel volume per ton of capacity and does not provide the ability to operate in both directions equally well.

Inability to climb grades of 8 to 12 percent at adequate speeds.

Operator required for each vehicle.

Small clearances, high speeds, and massive equipment combine to produce long delays in case of malfunction, and serious injuries in event of accident.

Combustion products complicate ventilation unless vehicles are powered electrically.

### Applicability

MDN's 1 through 5 can be transported by free vehicles. Excessive tire wear could be expected in the MDN 1 and 2 range due to angularity and abrasiveness of these materials. This system may not be practical for sites producing muck in the MDN 6 and 7 range because of traction and roadbed maintenance problems.

## SEMICONTINUOUS SYSTEMS

### Belt Conveyors

#### Capabilities and Advantages

Possible installation overhead or at sides of tunnel leaves floor space for other uses.

Capacities can be increased by changing belt speed.

Conveyors can go up or down slopes to 22 degrees.

### System Constraints

Supplementary transportation which must be provided for incoming materials and personnel.

Delays inherent as the conveyor is extended from a temporary to a semipermanent installation.

### Applicability

All MDN's can be transported by conveyors. Excessive belt damage and wear can be expected in the MDN 1 and 2 range because of piece size and shape unless the material is crushed prior to being placed in the system. In the MDN 6 to 7 range, through a wide range of water occurrence, considerable material will stick to the belt causing excessive cleaning problems. In the entire MDN range it is mandatory that the water content be below the point where the muck will slip or flow on the belt or overflow the sides.

### Hydraulic Pipelines

#### Capabilities and Advantages

Capacities adequate for the tonnage from any tunnel in the foreseeable future.

Pipelines use very little space in the tunnel.

Especially adaptable to very wet sites and to hydraulic excavation systems.

Adaptable to any grade, including vertical.

#### System Constraints

Capacity to handle plus 1-inch to plus 2-inch material through centrifugal pumps has not been demonstrated in field usage. Crushing or scalping equipment for through-centrifugal pump systems, or lock-feed equipment for alternate designs may cause congestion in the near face area.

Large amounts of water are required.

Required electrical power may be difficult to provide for long tunnels in remote areas.

Dewatering, recirculation, and muck disposal systems may be elaborate.

For high advance rates, methods of advancing pumping units and pipelines must be developed.

The heat load from large electrical installations may be difficult to dissipate.

System malfunctions may be hazardous to personnel.

### Applicability

MDN 7 is best suited for pumping because of the low percentage of plus #4 material and a high fines content. Preliminary screening and/or crushing would be needed for transporting all MDN's by a through-centrifugal pump system.

### Pneumatic Pipeline

#### Capabilities and Advantages

Pipelines use very little space in the tunnel.  
Adaptable to any grade, including vertical.

#### System Constraints

Power requirements appear excessive.  
Muck must be relatively dry.  
Crushing or scalping equipment must be used if pieces are too large for system.  
Pipe wear and maintenance may be excessive.  
Secondary transportation must be provided for materials and personnel.  
Methods of advancing blower units and pipe must be developed.  
Dust at the discharge or from malfunctions may be hazardous to personnel.

### Applicability

MDN 7 is best suited for pneumatic systems because of the low percentage of plus #4 material and the high fines content. Preliminary screening and/or crushing would be needed for transporting all MDN's.